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# **Users Manual for the Federal Aviation Administration Research and Development Electromagnetic Database (FRED) for Windows**

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Final Report

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## LIST OF ABBREVIATIONS AND SYMBOLS

A/m	Amps per meter
A/s	Amps per second
API	Application Program Interface
ASCII	American Standard Code for Information Interchange
C/m	Coulombs per meter
CD	Compact Disk
CEAT	Centre d'Essais Aeronautique de Toulouse
DBA	Database Administrator
DIR	Direct
DLL	Dynamic Linked Library
DSF	Data Scale Factor
EMA	Electro Magnetic Applications, Incorporated
eps	epsilon
FAA	Federal Aviation Administration
FM	Frequency Modulation
FRED	FAA Research and Development Electromagnetic Database
FTP	File Transfer Protocol
GPIB	General Purpose Instrument Bus
GSC	Galaxy Scientific Corporation
GUI	Graphical User Interface
Hz	Hertz
I	Current
ID	Identification
IDOT	Derivative Current Sensor
ILW	Current Sensor on Left Wing
ILW-L	Current Sensor on Left Wing - Low Frequency
INEEL	Idaho National Engineering & Environmental Laboratory
JNFF	Normal Current Sensor on Forward Fuselage
JNFF-H	Normal Current Sensor on Forward Fuselage - High Frequency
JNFF-L	Normal Current Sensor on Forward Fuselage - Low Frequency
JNLW	Normal Current Sensor on Left Wing
JS	Surface Current Sensor
JSAF	Surface Current Sensor on Aft Fuselage
JSFF-L	Surface Current Sensor on Forward Fuselage - Low Frequency
JSLW	Surface Current Sensor on Left Wing
JSRW	Surface Current Sensor on Right Wing
k	kilo
MAX	Maximum
mm	millimeter
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
nsec	nanosecond

ONÉRA	Offices Nationales des Études et Recherches Aérospatiales
PC	Personal Computer
PCM	Pulsed Coded Modulation
PPP	Point-to-Point Protocol
rms	root mean square
ROM	Read-Only Memory
RSF	Record Scale Factor
SD	Standard Deviation
SLIP	Serial Line Interface Protocol
SQL	Structured Query Language
SSF	Sensor Scale Factor
SSFDS	Sensor Scale Factor Data Scale
V	Volt
V <sub>p</sub>	Peak Value
WINSOCK	Windows Socket

## EXECUTIVE SUMMARY

This document provides instructional guidelines to users of the Federal Aviation Administration (FAA) Research and Development Electromagnetic Database (FRED). Instructions are provided on how to access FRED from a compact disk (CD) and how to access the entire set of waveforms. The lightning strike waveforms have been collected from various FAA tests (which have been stored on the Idaho National Engineering & Environmental Laboratory (INEEL) computers) and can be accessed via the Internet or dial-up modem.

The lightning strike data contained in FRED are described, including how the data were acquired and processed for entry into FRED.

Troubleshooting information is also provided, along with error message descriptions and corrective actions. For further information contact Kurt Wagner of INEEL at (208) 526-9531.



## 1. INTRODUCTION.

### 1.1 BACKGROUND.

Researchers throughout the world have conducted research on lightning. In general, once a researcher has published data and conclusions, it is difficult for others to access that data. To overcome this problem, the Federal Aviation Administration (FAA) has solicited data from several sources to be compiled into the FAA Research and Development Electromagnetic Database (FRED). Currently, airborne data from the CV-580, the National Aeronautical and Space Administration's (NASA) F-106 program, and the French Transall C-160 data reside in the database.

Following extensive testing of the FRED environment, it was determined that the use of Windows technology would make FRED more user-friendly. The result is *FRED for Windows*, described by this Users Manual.

*FRED for Windows* is a personal computer (PC) -based application which allows the user to access basic data about lightning strikes on the user's own PC. In addition, extensive waveform data is housed on a FRED Data Server at the Idaho National Engineering & Environmental Laboratory (INEEL) in Idaho Falls, Idaho.

FRED includes information compiled by researchers using different equipment and having various research goals. As a result, some records may not have data in all fields.

*FRED for Windows* can be used to view information that has been collected, plan future physical or statistical research projects, and test lightning models.

The database supports the following functions:

- Database browsing
- Ad hoc database queries
- Waveform processing
  - Plot generation
  - Data reduction by decimation, filtering, range, min/max, and averaging
  - Data manipulation functions for the integration and differentiation of waveforms

### 1.2 FRED DATA.

FRED contains three types of data: environmental, electromagnetic, and waveform. At a minimum, there will be environmental and electromagnetic data for each strike. A *FRED for Windows* compact disk (CD) contains all of the environmental and electromagnetic data. In addition, two subset waveforms are provided for each waveform in FRED. One subset waveform contains a thousand data points around the peak of the waveform (250 before the peak and 750 after). The other subset contains a thousand data points which are min/max range points selected over the entire waveform to give the user an overall picture of the waveform without fine structure detail.

The following sections describe the data fields in FRED. The default value for each field is given. In general, the numeric default value will be some value that is physically or logically impossible to obtain. For the alphabetic default, the letter "U" or the word "Unknown" will be displayed.

### 1.2.1 Environmental Data.

Environmental data consists of data that describes the environment at the time of the strike. Air temperature, airspeed, and precipitation type are examples. Table 1 shows the possible environmental data fields and their default or unknown values.

TABLE 1. ENVIRONMENTAL DATA

Field	Default Value	Origin
STRIKE TYPE	blank	log sheet
ALTITUDE	-9999	log sheet
AIRSPEED	-9999	log sheet
OUTSIDE AIR TEMPERATURE	-999	log sheet
ELECTRICAL PHENOMENA	blanks	log sheet
PRECIPITATION SEVERITY	9	log sheet
TYPE OF PRECIPITATION	9	log sheet
TURBULENCE SEVERITY	9	log sheet
ATTACHMENT POINT	blanks	log sheet
DETACHMENT POINT	blanks	log sheet

Latitudes and longitudes are not shown in table 1. Although various data sources may contain strikes for which this information is not available, these values have been estimated. The default latitudes and longitudes for data sources in FRED are shown in table 2.

TABLE 2. DEFAULT LONGITUDES AND LATITUDES

Data Source	Latitude	Longitude
CV-580	28:00:00 N	81:00:00 W
NASA F-106	38:00:00 N	75:00:00 W
Transall C-160	43:30:00 N	1:30:00 E

### 1.2.2 Electromagnetic Data.

Electromagnetic data consists of electromagnetic parameters that can be calculated from a waveform or sensed directly. Table 3 shows the possible electromagnetic data fields and their default values. Fields whose default values are marked with an asterisk (\*), do not have default values. If the value is unknown, no record will be made because the rest of the fields cannot be evaluated.

TABLE 3. ELECTROMAGNETIC DATA

Field	Default Value	Origin
SENSING PARAMETER	*	Documentation
PEAK VALUE OF PARAMETER	0	Calculation
TIME TO PEAK VALUE OF PARAMETER	0	Calculation
PEAK RATE OF RISE OF PARAMETER	0	Calculation
TIME OF PEAK RATE OF RISE	0	Calculation
FULL WIDTH AT HALF MAXIMUM VALUE	0	Calculation
TIME TO HALF MAXIMUM VALUE	0	Calculation
NOISE WAVEFORM FLAG	NO	Calculation
SATURATION FLAG SET	U	Documentation
INTEGRATION START AND STOP TIMES	blank	Calculation
ACTION INTEGRAL	blank	Calculation
ACTION INTEGRAL ERROR	blank	Calculation
CHARGE TRANSFER	blank	Calculation
CHARGE TRANSFER ERROR	blank	Calculation
TRIGGER THRESHOLD	-9999	Documentation
SATURATION THRESHOLD	-9999	Documentation
FULL SCALE	-9999	Documentation

### 1.2.3 Waveform Data.

Waveform data consists of data points recorded either by a digital or an analog recorder. If the waveform was recorded in analog format, it was digitized before it was included in FRED. Waveform data included in the user's *FRED for Windows* installation package consists of two waveform subsets for each waveform in FRED. One subset is 1000 points around the peak (250 before the peak and 750 after). The other is 1000 points which represent the minimum and maximum data points in intervals evenly spaced across the whole waveform. The entire set of waveforms are available at the INEEL and are accessed via the Desired Attributes for Plotting Waveform #n window. The window indicates the number of data points in the waveform and provides data reduction methods for downloading a portion of the waveform.

### 1.2.4 Other Data.

In addition to the data described above, FRED carries other information describing the lightning event and its measurement. Specifically, this data describes the data source or the collection equipment. These fields are shown in table 4. Fields whose default values are marked with an asterisk (\*) do not have default values.

TABLE 4. OTHER DATA

Field	Default Value
SOURCE TYPE	blank
SOURCE NAME	*
PRIMARY RESEARCHER	blank
RESEARCHER'S AFFILIATION	*
DATE OF FLASH	*
TIME OF FLASH	*
TIME OF INITIAL SAMPLE POINT	U
SENSOR LOCATION	blank
DIGITIZER ID	0
SAMPLING INTERVAL	0
SAMPLING WINDOW	0
ANALOG RECORDER ID	0
MANUFACTURER	blank
MODEL NUMBER	blank
SENSOR TYPE	blank
LOWER FREQUENCY RESPONSE LIMIT	0
UPPER FREQUENCY RESPONSE LIMIT	0
ACCURACY	blank
NUMBER DISCRETIZATION LEVELS	0
NUMBER OF CHANNELS	0
MAXIMUM FM BANDWIDTH	0
MAXIMUM DIRECT RECORD BANDWIDTH	0
FULL SCALE	0
DYNAMIC RANGE	0
SENSOR SCALE FACTOR	*
RECORD SCALE FACTOR	*
DATA SCALE FACTOR	*
NUMBER OF POINTS	*

### 1.3 DATA SOURCES.

Currently, FRED contains data from the FAA's CV-580 program, the NASA's F-106 program, and the French Transall program. The data from each of these programs represented an effort of data retrieval, manipulation, and verification before input into the FRED database.

### 1.3.1 CV-580 Data.

During 1984, 1985, and 1987, the FAA recorded electromagnetic measurements of lightning strikes to a Convair 580 aircraft that was flown in Florida thunderstorms. This program was conducted jointly with the Air Force, Navy, NASA, the National Oceanic and Atmospheric Administration (NOAA), and the Offices Nationales des Études et Recherches Aérospatiales (ONÉRA). The Convair 580 was hardened against lightning. During the course of the program, the aircraft was struck approximately 60 times.

Three types of data were collected: digital recordings, analog recordings, and manually written log sheets. The log sheets contain information about the environment, such as the altitude, temperature, airspeed, and precipitation and turbulence conditions. They also contain the date and time of the strike and the aircraft's position (longitude and latitude) when it was struck.

The CV-580 aircraft had several sensors located throughout the structure. The number, types, and locations of the sensors varied from one year to the next. The sensors fed both analog and digital tape recorders. The analog recorders ran continuously during the flight, except when a tape ran out and a new tape was being mounted. Analog recordings were made of 48 strikes to the aircraft. The analog signals were converted to digital representations by Electro Magnetic Applications, Incorporated (EMA). The staff at the INEEL entered the digitized analog data, the digital data, and the data from the log sheets into FRED.

### 1.3.2 NASA F-106 Data.

Between 1981 and 1986, NASA studied lightning at high atmospheric levels. An instrumented F-106 aircraft was flown into storm clouds. NASA collected data on strikes that occurred near the aircraft as well as those that directly hit the plane. Although both analog and digital waveforms were collected, only the digital waveforms were available for incorporation into FRED. The F-106 Program recorded data similar to that collected in the CV-580 program and also environmental data.

### 1.3.3 French Transall Data.

The French flew a Transall aircraft in both 1986 and 1988. Analog recordings were made in 1986 and both analog and digital recordings were made in 1988. Current and current density measurements were taken in 1986; and current, electric, and magnetic field measurements were taken in 1988. The digital recordings primarily covered the attachment phase of the lightning strike.

## 2. DATABASE AND USER MANUAL INFORMATION.

### 2.1 THE FRED ENVIRONMENT.

*FRED for Windows* is a Windows-based application program which provides multiple ways to access FRED's descriptive, environmental, electromagnetic, and waveform data. It also provides processing options and plotting capabilities. The descriptive, environmental, and electromagnetic

data are provided as part of the PC-resident application in a local database. In the CD-ROM version, two overview plots are also included for each waveform. Entire waveforms are processed remotely at the INEEL per the user's processing selections to reduce the data or to perform integration or differentiation calculations. (This is referred to as "downloading waveforms.") The resulting plot data are returned to the user's PC for plotting and to be saved. Figure 1 shows the FRED environment.

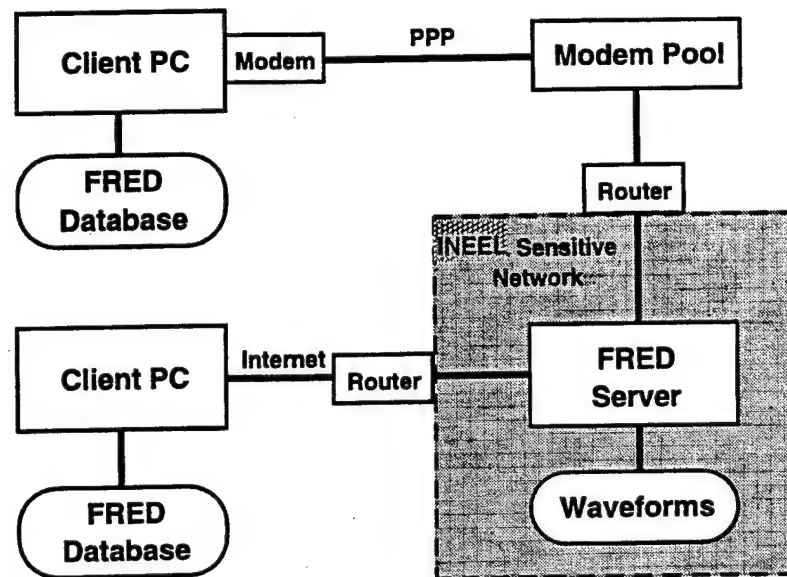


FIGURE 1. SYSTEM BLOCK DIAGRAM

There are two methods to access the complete waveforms at the INEEL. *FRED for Windows* allows users who have network access through their own computer (i.e., access to the Internet) to connect directly to the FRED Data Server on which the waveforms are stored. The appropriate addressing information is already in *FRED for Windows*. Users who do not have network access will need a modem and TCP/IP/PPP communications software that provides a Windows dynamic linked library (DLL) that is Windows Socket (WINSOCK) compliant and supports point-to-point (PPP) or serial line interface protocol (SLIP).

## 2.2 FRED DATA STRUCTURE.

The data in FRED is organized in a hierarchical structure. For each source of data, there is a source record which shows the name of the source, the names of the researchers who acquired the data, and the affiliation of those researchers at the time the data was acquired. Figure 2 shows the relationships among data entities.

For each source, there will be one or more flashes. Each flash record corresponds to one lightning event. The flash record contains information about the conditions at the time of the strike, such as temperature, precipitation type, altitude, and airspeed. These are conditions that are common to all waveforms resulting from the strike.

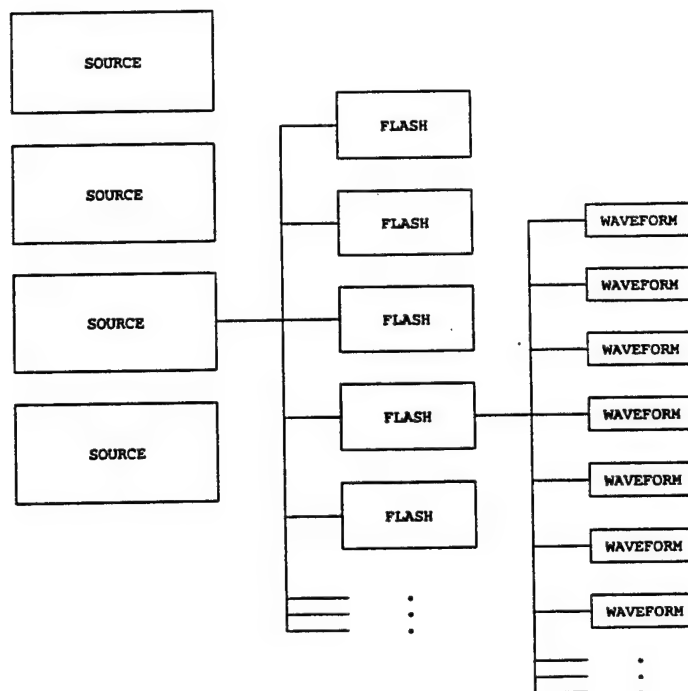


FIGURE 2. DATA RELATIONSHIPS

For each flash record, there will be one or more waveform records. Each waveform record is a recording of the waveform output by one sensor. The number of waveform records is determined by the number of channels of data recorded during the lightning event.

For each waveform record, there will be only one electromagnetic data record. The electromagnetic data have been calculated from the associated waveform. The data consist of discrete electromagnetic parameters, such as peak value and peak rate of rise. For current waveforms, the action integral and charge transfer are also calculated and stored in the electromagnetic data record.

The flash numbers and waveform numbers were assigned sequentially when the data was entered into FRED. As a result, the numbers in some sources may not be consecutive or there may be gaps in the sequence. For example, all the CV-580 analog data was entered into FRED before the CV-580 digital data was entered. So the analog waveform numbers are sequential, but there is a gap in the sequence between the analog and digital waveform numbers.

### 2.3 DATABASE LANGUAGE AND CONVENTIONS.

FRED data are accessed through a Windows point-and-click interface. The data can be viewed hierarchically by selecting the **Open Sources** icon which displays a scrollable list of sources. Double-clicking on a source displays a scrollable list of all flashes for the selected source. Likewise, double-clicking on a flash displays information on each of the sensors that collected data during a flash, the electromagnetic parameters that were collected, and the analog recorder or digitizer. At any point a detail report can be viewed on a single item (e.g., sensor) that is displayed. At the sensor level, two overview plots can be viewed or customized plots can be created.

The ad hoc report option (**Run the Ad Hoc Report** icon) provides a crosscut report feature. The user can select any fields of interest, sort the results, and restrict the set of results (filter).

Data can be saved in other formats (e.g., Excel, Quatro Pro, dBase, etc.) for manipulation in other software or reporting packages, or the data can be copied (using the standard Windows Edit-Copy feature) to the clipboard.

Environmental plots are available for plotting peak current or peak rate of rise versus latitude, longitude, altitude, and temperature.

Finally a structured query language (SQL) interface is available for constructing database queries. This option is recommended only for those experienced with SQL.

## 2.4 HELP FUNCTION.

The Help function has two actions, depending on the situation from which it is invoked. If an error message has appeared and the Help function is invoked, the error message is explained. When the Help function is invoked from other windows, appropriate help information will appear.

## 2.5 ERROR MESSAGES AND FAULTS.

### 2.5.1 General Error Messages.

Appendix A lists error and information messages in alphabetical order by the first word of the message. The first column shows the error message. The second column shows the result of acknowledging the error message. The last column indicates actions that the user might consider to correct the error condition.

Appendix A contains known error messages; however, it may not be comprehensive, as Oracle<sup>TM</sup> bugs and system glitches could generate messages that are not on this list. If an undocumented message appears, attempt to obtain a screen print containing the message. Also, document the sequence of events that led up to the message. Then, contact the FAA Database Administrator (DBA) with this information so that the problem can be resolved and documented. (Comment sheets are included at the end of this manual. They may be used to report error problems or to request enhancements and improvements.)

### 2.5.2 General Protection Faults.

One particular class of errors requires discussion here: General Protection Faults. One source of general protection faults is errors which are generated when Windows applications require more memory or system resources than are available. All Windows applications use memory and system resources. When a Windows application is closed it will release memory and system resources. However, some Windows applications do not release all of the resources which they appropriate. The other resources are only released when Windows is closed.



When a General Protection Fault occurs, the user should close all Windows applications and then close Windows itself. This will release all memory and system resources still being held. It is not necessary to reboot the system.

Typically, this type of error occurs when the user has too many Windows applications active simultaneously. However, some screen saver programs appropriate resources each time they are invoked. If general protection faults occur on a regular basis, the user should consider using a different screen saver, or not using a screen saver at all.

### 3. ACCESSING FRED.

#### 3.1 REQUESTING ACCESS TO FRED.

Before accessing the database, it is necessary to request access and obtain a user ID by completing the following steps:

- a. Send or fax a "request for access" letter to the FRED FAA DBA at AAR-421, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey 08405. Include the nationality and business or academic affiliation of each person who will be a user. There is no charge for accessing data from the FRED Data Server or for receiving the Version 1.0 CD-ROM at this time. However, users requiring technical support or wishing to fund additional enhancements or data additions to the system should contact K. Wagner (INEEL) at (208) 526-9531.
- b. After the DBA has received the request, the FAA will send a *FRED for Windows* installation package to the requestor. The installation package will contain a CD (or installation diskettes), forms for requesting access to the FRED Data Server, and information on the registration process.

#### 3.2 SYSTEM REQUIREMENTS.

To run *FRED for Windows*, the user will need a 386 PC or better, running Windows 3.1 (or later). At least 8 Megabytes of RAM are required, along with about 2 Megabytes of disk space. If the user wishes to download waveforms from the FRED Data Server, additional disk space will be required along with communications software and a communication link or modem.

#### 3.3 WINDOWS CONVENTIONS.

*FRED for Windows* has a Windows-based graphical user interface (GUI). The standard Windows features and tools are present in the application. For example, the printer selected under Windows is active within this application and the colors selected under the Windows Desktop are used within *FRED for Windows*. As in Windows, the GUI works best with a mouse; not all functions and windows can be accessed from the keyboard. The user who is unfamiliar with Microsoft Windows should take the time to read the Windows documentation. The standard Windows controls for closing, minimizing, moving, resizing, and tiling windows are available. Scroll bars are used to view information that is "scrolled off the window."

The left mouse button is typically used to make menu selections, to do Windows operations (resizing, etc.), and to move the cursor to a field on the screen. Holding the <Shift> key while making a second selection selects everything in the range. Holding the <Ctrl> key while making a selection allows multiple distinct items to be selected (as the application permits).

The right mouse button is used to bring up commands available on that window. It provides short cuts to menu options.

The Windows <Alt><Tab> combination can be used to rotate through applications currently running under Windows. This is useful for switching between *FRED for Windows* and wgnuplot, the Windows plotting package, for plots previously displayed.

Certain menu options are not available under all situations. If an option is not available, its menu entry is faded out. Clicking on a faded entry does nothing.

### 3.4 WINDOWS SETUP.

The colors used in *FRED for Windows* are selected (and may be changed) through the **Color** icon in the Windows Control Panel. Double-clicking on the **Control Panel** icon will open the Control Panel window. Double-clicking on the **Color** icon in the Control Panel window opens the Color window. The user may select from the preset color schemes by clicking on the arrow in the Color Schemes block and then clicking on the desired scheme. The user may also set the colors for individual sections of the desktop by clicking on Color Palette. See Windows manuals for further information.

The user is cautioned that in some color schemes, some of the data “disappears” from the windows because it is printed in color on color (i.e., blue on blue). This problem is corrected by choosing a different color scheme.

In addition, some color schemes translate into excessive shading in printed reports. If the headers in printed reports are hard to read, a different color scheme may need to be selected.

*FRED for Windows* uses the Windows Print Manager to interface with the user's printer. If the Windows Print Manager is not set up with the appropriate print drivers, reports will not print correctly. See the Windows manuals for troubleshooting printing problems.

### 3.5 FRED FOR WINDOWS INSTALLATION.

Once the user's request for access to FRED has been processed and approved, the user will receive a package of software and data to be loaded onto a PC. The information will be provided on either a set of floppy disks or a CD-ROM. In either of these cases, the user will load FRED by inserting the first disk and following the instructions on the disk. This will start the installation process.

During installation, the user will be asked if files should be overwritten. The user may reply “No” to all questions except replacement of the autoexec.bat file. The change to the autoexec.bat file will include the FRED directory in the search paths.

### 3.6 ACCESSING FRED FOR WINDOWS.

The user's *FRED for Windows* installation package will also include a user ID and password to be used to access the FRED waveforms installed on the FRED Data Server. If requested, a password will also be provided to allow access to FRED through a dial-up line. No passwords are needed to access FRED on the user's own PC. The passwords are only required if the user wants to work with the complete waveforms instead of the subset waveforms provided with *FRED for Windows*.

Once *FRED for Windows* has been installed, the user may open it by double-clicking on the FAA icon. An SQL icon will be opened for the WATCOM driver. The Lightning Strike Data window will also be opened. This will allow the user to access *FRED for Windows* and all of the data which are provided with *FRED for Windows*. The user may employ a mouse and click on the icons, or access various windows by holding down the <ALT> key and pressing the underlined letter of the desired menu. Not all options are available at all times. If an option is not available, its menu entry is dim or its icon is not shown.

NOTE: *FRED for Windows* will access the drive containing the default plots when *FRED for Windows* is invoked to ensure that the drive is available. This operation requires that a CD or disk be in the drive indicated in the Plot Location option under the File menu. If the user does not intend to access the default plots, the plot locations may be set to nulls to avoid needing a CD in the drive.

If the user is not interested in accessing any data beyond that provided with the installation package, the user will not need communications software. The user who is interested in working with the basic waveform data should review paragraph 3.7.

### 3.7 COMMUNICATIONS SOFTWARE SETUP.

The procedure to access the complete waveform data from the INEEL depends on whether the user has access to the Internet or will be dialing in. In either case, the user may wish to determine all remote requests to minimize remote connect time.

*FRED for Windows* assumes that an Internet connection has been established when the user is ready to download a portion of a waveform from the INEEL. For a direct Internet connection no action is required beyond having the software resident on the PC and the network physically connected. For a modem connection, the user must switch applications (use <ALT><TAB> to return to the Program Manager) and make the modem connection to the FRED Data Server using the PC's communication software. Once the connection is established the procedure to obtain waveform data is identical for both methods. (Return to *FRED for Windows* by again using <ALT><TAB>.)

#### 3.7.1 Internet Connection.

An Internet connection requires a WINSOCK application program interface (API) compliant DLL.

### 3.7.2 Modem Connection.

Modems of 9600 baud or faster are preferred. INEEL supports up to V32.bis (16,384 baud x factor of 4 compression). The telephone number for a modem connection is 1 (800) 330-6712. The communication software must support PPP or SLIP that emulates an Internet connection and must be WINSOCK compliant.

The Chameleon Sampler shareware software is available from Netmanage at <ftp.netmanage.com>. The directory is called `\pub\demos\sampler`. There are two files: `sampler.exe` and `readme.txt`. Other packages such as FTP's OnNet and Distinct work equally well.

To access the network on which FRED resides, the user will need an NCC user ID and password. Forms to request them are included with the *FRED for Windows* installation package. In addition, the user will need the information in table 5 to access FRED.

TABLE 5. FRED REMOTE ACCESS INFORMATION

Interface	FAA SERVER - COM3, 9600 baud ( <i>or greater</i> )
Dial	1-800-330-6712
IP Address	1.1.1.1
Subnet Mask	255.255.255.128
Domain Name	inel.gov
User ID	NCC User ID.p [Append .p to the NCC User ID]
NCC Password	

Once the connection is established, the procedure to obtain waveform data is identical for both methods. *FRED for Windows* will prompt for the *FRED for Windows* user ID and password when a waveform is selected for processing (refer to paragraph 13.1.1). If the password is incorrect, the PC will not be connected to the remote machine and no waveforms will be downloaded.

When no more data are to be downloaded, it is recommended that the user close the modem connection to free up the connection and telephone line for other users.

## 4. RELATIONSHIP OF WINDOWS AND ICONS.

The following is the relationship of the windows and icons

- **Open Sources Icon**
  - {Sources Window}
    - **Print the Current Sheet Icon**
    - **Save Rows to File Icon**
      - {Save Rows As Window}

- **Run the Ad Hoc Report Icon.**
  - {Ad Hoc Reporting Window}
  - {Queried Report Window}
- **SQL Reporting Capability Icon**
  - {SQL Query Window}
  - {Queried Report Window}
- **Environmental Information Icon**
  - {Query Limits Window}
  - {Queried Environmental Flashes Window}
    - {Waveforms in Flash #n (Queried Environmental Flashes) Window}
      - **Plot the default minmax waveform Icon**
      - **Plot the waveform around the peak Icon**
- **Request/View Plots Icon**
  - If plots have already been downloaded for this waveform: {Plots for Waveform #n Window}
  - If no plots have already been downloaded for this waveform: {Desired Attributes for Plotting Waveform #n Window}
  - {Environmental Plot Options Window}
    - {Plot of selected plot parameters Window}
- **Close Icon**
- **Provide User Help Icon**

## 5. OPEN SOURCES ICON.

Clicking on the **Open Sources** icon causes the Sources window to be opened.

### 5.1 SOURCES.

The Sources window shows information on the data sources in FRED including the source name, the original researchers, the affiliation of the researchers, and whether airborne or ground-based sensors were used to capture the data. When this window is active, the **Print the Current Sheet** and **Save Rows to File** icons are shown.

#### 5.1.1 Flashes in Source xxxx.

Double-clicking on a source in the Sources window causes the Flashes in Source xxxx window to be opened.

For each of the flashes in the selected source, the following information is presented: the flash ID, the date of the flash, the time of the flash (start time), the turbulence severity, the type of precipitation, and whether the strike attached directly to the sensor platform or passed nearby.

Clicking on the right mouse button or double-clicking on the left mouse button while a flash is highlighted causes the Flash #n Detail window to be opened. This window displays the following information for the highlighted flash: the flash ID, the flash date, the start time, the trigger initiation time, the altitude, airspeed, air temperature, turbulence severity, the longitude and latitude at which the flash was recorded, the attachment and detachment points if known, whether the strike attached directly to the sensor platform or passed nearby, the precipitation type, whether other electrical phenomena occurred around the time of the flash, and the source of the recording trigger.

Unless the user closes the Flash #n Detail window, highlighting another flash and clicking the right mouse button or double-clicking on the left mouse button causes the existing Flash #n Detail window to be brought to the front of the window stack. It will contain the previously requested information. To get the detail information on another flash, the user will need to close the Flash #n Detail window before trying to reopen it.

#### 5.1.1.1 Flash #n (xxxx).

Double-clicking on a flash in the Source xxxx window causes the Flash #n (xxxx) window to be opened. This window contains the following information on the individual waveforms for the selected flash: the waveform ID and type (analog or digital), the noise flag, the sensing parameter, the instantaneous peak rate of rise and its units, the location of the sensing parameter, the location of the peak rate of rise in the waveform, the peak value and its units, the saturation flag, the low- and high-frequency limits, the full width at half maximum, the full scale and its units, the time to peak, the time for the waveform to rise to half maximum, the location of the peak in the waveform, the high- and low-saturation thresholds, the trigger threshold, the sampling window and interval, and the number of data points in the waveform.

The following information is provided to describe the digitizer that recorded the waveform or that converted it from an analog to a digital waveform: the manufacturer, the model, and the number of discretization levels.

In addition, if the waveform was originally recorded as an analog waveform, the following information is provided: the manufacturer, the model, the number of channels, the maximum FM bandwidth, the maximum direct bandwidth, the full scale, and the dynamic range.

The following information about the sensor which captured this waveform is provided: the manufacturer, the model, the type, the upper- and lower-frequency responses, the accuracy, and a description.

If the sensing parameter is I, this window shows the action integral, action-integral error, action-integral system error, the charge transfer, the charge-transfer error, the charge-transfer system error, and the integration start and stop points.

An additional field is provided for comments.

## 6. RUN THE AD HOC REPORT ICON.

Clicking on the **Run the Ad Hoc Report** icon causes the Ad Hoc Reporting window to be opened.

### 6.1 AD HOC REPORTING.

In the Ad Hoc Reporting window, columns are selected for inclusion in the report by double-clicking on the desired column or by positioning the mouse on the desired column and holding the left mouse button down while dragging the item into the Data Columns To Show block. (The user may delete a column from the report by double-clicking on that data element in the Data Columns To Show block.)

Columns will appear in the report in the order in which they were selected, (i.e., each column added goes to the end of the list). However, the order of the report may be changed once the query has been requested.

Once the user has selected all the desired columns, clicking on the Query block causes the report to be generated and shown in the Queried Report window.

#### 6.1.1 Queried Report.

The Queried Report window shows the result of the query created in the Ad Hoc Reporting window. Columns may be reordered within the report by clicking on the column to be moved and holding the left mouse button while dragging the column to its new position.

While the Queried Report window is active, the Rows menu is available. Clicking on this menu allows the user to sort (paragraph 17.1) and filter (paragraph 17.2) the active report.

## 7. SQL REPORTING CAPABILITY ICON.

Clicking on the **SQL Reporting Capability** icon causes the SQL Query window to be opened. The user may type the desired query; however, only select statements are permitted. Clicking on the Query box implements the query if it is valid. If the query is not valid, the SQL Syntax Error window is displayed. This window contains information about the nature of the syntax error.

The user is cautioned that improperly specifying the conditions on the select statement may result in an unreasonable number of rows being selected. If this happens, the query can take an unreasonable amount of time. It is the user's responsibility to avoid this situation. (Rebooting the computer is the only way to abort this function.)

If a valid query was issued, FRED assembles a report and displays it in the Queried Report window (see paragraph 6.1.1).



## 8. ENVIRONMENTAL INFORMATION ICON.

### 8.1 QUERY LIMITS WINDOW.

Clicking on the **Environmental Information** icon causes the Query Limits window to be opened. The user may change the query limits by positioning the cursor in a limit box or by clicking on the boxes for N, S, E, or W. When the query limits are acceptable, the user may either click on Query to produce a default report or Plot to produce default plots.

If the user wishes to limit the longitudes under consideration, the user needs to exercise care in the selection of new limits. FRED considers that west longitudes are negative numbers and east longitudes are positive. As a result, the minimum west longitude is a number that is greater than the maximum west longitude. (The Transall data have east longitudes; the CV-580 and F-106 have west longitudes.)

This issue is not relevant to latitudes at this time since the CV-580, F-106, and Transall data all have north latitudes and FRED considers north latitudes to be positive numbers.

#### 8.1.1 Query Limits—select query.

Clicking on the Query box in the Query Limit window causes a default report to be generated and displayed in the Queried Environmental Flashes window.

##### 8.1.1.1 Queried Environmental Flashes.

For each of the flashes, the following information is presented: the flash ID, the altitude, the airspeed, the air temperature, the latitude and longitude at which the flash was recorded, the date of the flash, and the time of the flash (start time).

Double-clicking on a flash in the Queried Environmental Flashes window causes information on all the waveforms associated with that flash to be displayed in the Waveforms in Flash #n (Queried Environmental Flashes) window.

##### 8.1.1.1.1 Waveforms in Flash # n (Queried Environmental Flashes).

Double-clicking on a flash in the Queried Environmental Flashes window causes the following information on all the waveforms associated with a given flash to be displayed in the Waveforms in Flash #n (Queried Environmental Flashes) window: the waveform ID, the peak value and its units, the instantaneous peak rate of rise and its units, the Action Integral, and the Charge Transfer.

Clicking on the right mouse button or double-clicking on the left mouse button while a waveform is highlighted causes the Waveform #n Detail window to be opened. This window displays the following information for the highlighted waveform: the waveform ID, the aircraft location description, waveform type, aircraft general location or orientation, noise flag, EMA label, sensing parameter, saturation flag, the peak value, the time of the peak value, the peak rate of rise, the peak rise time, the time to peak, the sampling window, the full width at half of the peak, the sampling



interval, the time to half peak, the saturation high and low values, the trigger threshold, the high- and low-frequency limits, the full-scale value.

In addition, for current waveforms, the following information is provided: the action integral and charge transfer and estimated error values for these quantities, the integration start and stop times, and comments.

The following information is provided on the digitizer: the manufacturer, the model number, and the number of discretization levels.

The following information is provided on the analog recorder: the manufacturer, the model, the maximum FM bandwidth and the maximum bandwidth, the dynamic range, full scale, and the number of channels.

The following information is provided on the sensor electronics: the manufacturer and model, the lower and upper frequency responses, the accuracy, and the sensor type.

Unless the user closes the Waveform #n Detail window, highlighting another waveform and clicking the right mouse button or double-clicking on the left mouse button causes the existing Waveform #n Detail window to be brought to the front of the window stack. It will contain the previously requested information. To get the detail information on another waveform, the user will need to close the Waveform #n Detail window before trying to reopen it.

#### 8.1.2 Query Limits—select plot.

Clicking on the Plot box in the Query Limits window causes the Environmental Plot Options window to be opened.

##### 8.1.2.1 Environmental Plot Options.

In the Environmental Plot Options window, the user may select either the Peak Current or the Peak Rate of Rise (Peak Rise) to be plotted on the Y axis. For the X axis, the user may select one of Latitude, Longitude, Temperature, or Altitude. These selections are made by clicking on the appropriate circle.

The user may accept the default titles, or may change them by typing in the appropriate box. Changing the X or Y axis parameters changes the title information, so these selections should be made before changes are made to the default titles.

When the user is satisfied with the selections, clicking on the Plot box generates the plot. More than one of these plots may be open on the desktop at a time.

#### 8.1.2.1.1 Plot of selected plot parameters.

The Plot of *selected plot parameters* is generated by FRED when Plot is selected from the Environmental Plot Options window. If the user clicks on the Save Rows to File icon, a query-type report which could be used to create a similar plot will be saved, not the actual plot. The system determines the axis limits; the user cannot change the system selections.

#### 9. PRINT CURRENT SHEET ICON.

Clicking on the **Print the Current Sheet** icon causes FRED to prepare a print spool file and a Print: default printer name and port window to be opened. This window shows the status of the print job, the default printer and printer port, and allows the user to cancel the print job. Printing is handled by the Windows Print Manager, not by *FRED for Windows*. Print error messages are handled by the Windows Print Manager.

#### 10. SAVE ROWS TO FILE ICON.

Clicking on the **Save Rows to File** icon causes the Save Rows As window to be opened. The default directory is shown under the file name box. The directory may be changed by including the complete path in the file name box. The file name field is changed by typing the new name and deleting any unnecessary characters.

The default file type is Excel. It may be changed by clicking on the bullet to the left of the desired file type. The file types are shown in table 6.

TABLE 6. AVAILABLE FILE FORMATS

<u>Excel</u>	Microsoft Excel format
<u>SYLK</u>	Microsoft Multiplan format
<u>DIF</u>	Data Interchange format
<u>Text</u>	Tab-separated columns with a hard return at the end of each row
<u>WKS</u>	Lotus 1-2-3 format
<u>DBF 2</u>	DBase 2
<u>DBF 3</u>	DBase 3
<u>CSV</u>	Comma separated values (for entering data into a database)
<u>SQL Syntax</u>	Insertion-type statements for entering data into a database
<u>WMF</u>	
<u>Report</u>	
<u>WK1</u>	

Headers may be included in the file by clicking in the box next to Include Headers.

Clicking on OK causes the file to be saved. If there is already a file with the same file name, a DataWindow will be opened so that the user may cancel the operation or allow it to continue. Clicking on Cancel in the Save Rows As window returns the user to the last active window.

## 11. PLOT THE DEFAULT MINMAX WAVEFORM ICON.

### 11.1 DEFAULT MIN/MAX.

The Default Min/Max waveform is a waveform of about 1,000 points. These points are minimum and maximum range points for intervals selected over the entire waveform to give the user an overall picture of the waveform without fine structure detail. The user does not need to download the default waveforms from the CD.

When the Waveforms in Flash #n (Queried Environmental Flashes) window or the Waveforms in Flash #n (source name) window is active, the **Plot the Default MinMax Waveform** icon (and the Default Min/Max element under the Plot menu) are available. (If not, check to see that the CD is in place and that the drive is working properly.)

#### 11.1.1 GNUPlot.

Clicking on Default Min/Max or the icon while a waveform is highlighted causes the graphics package GNUPlot to be opened in a gnuplot window. The selected plot will be uncompressed from the CD onto the C drive (in the default directory) and plotted from there. The user needs to ensure that space is available on the C drive for this plot.

GNUPlot plots the waveform in a gnuplot graph window. Only one plot may be displayed at a time. If a second plot is requested, an Error window is opened with the message: STOP Windows Execute Error: Cannot load second instance of multiple data segment application. Clicking on OK clears the message. To plot another waveform, the user must close the gnuplot window.

GNUPlot is a Windows program which is separate from and invoked by *FRED for Windows*. Returning to *FRED for Windows* causes the GNUPlot windows to go behind the *FRED for Windows* windows. <ALT><TAB> brings the GNUPlot windows to the front so that they can be closed.

## 12. PLOT THE WAVEFORM AROUND THE PEAK ICON.

The Default Peak waveform is a waveform of about 1,000 points around the peak of the waveform. The user does not need to download the default waveforms from the CD.

When the Waveforms in Flash #n (Queried Environmental Flashes) window or the Waveforms in Flash #n (source name) window is active, the **Plot the Waveform Around the Peak** icon (and the Default Peak element under the Plot menu) are available. (If not, check to see that the CD is in place and that the drive is working properly.)

Clicking on the icon or Default Peak in the menu causes the graphics package GNUPlot to be opened as described in paragraph 11.1.1.

### 13. REQUEST/VIEW PLOTS ICON.

The results of clicking on the **Request/View Plots** icon depends on whether the user has already downloaded waveforms for the referenced flash.

If no waveforms have already been downloaded for this flash, clicking on the **Request/View Plots** icon causes the Desired Attributes for Plotting Waveform #n window to be opened. (See paragraph 13.1.)

If waveforms have already been downloaded for this flash, clicking on the **Request/View Plots** icon causes the Plots for Waveform #n window to be opened. (See paragraph 13.2.)

#### 13.1 DESIRED ATTRIBUTES FOR PLOTTING WAVEFORM #n.

The complete path must be entered in the File Name field. The user must click on the Browse box which will activate the Compressed GNU File Select window. This window shows GNUPlot files which have already been downloaded to the user's directory. The user may select one of these files by double-clicking on the desired file. Otherwise, the user may type an existing or new file name in the space provided. If the user forgets to add an extension to the file name, a window will open with the message: ! filename.xxx This file name is not valid. Clicking on the OK box in this window will return the user to the Compressed GNU File Select window.

Clicking on the OK box in the Compressed GNU File Select window returns the user to the Desired Attributes for Plotting Waveform n window with the complete path and file name in the File Name field. Clicking on the Cancel box returns the user to the Desired Attributes for Plotting Waveform n window with the File Name field unchanged.

The user may customize the data to be downloaded by entering or changing values in the various boxes. Data may be considered as time values or data points. Data points is the default value. Clicking on the down arrow box next to the Select box shows both Points and Times. Clicking on the desired value causes that value to be selected. The times are in nanoseconds, as is shown next to the from and to boxes in the Select line.

The from and to boxes are used to limit the number of points to be downloaded. If no changes are made in these boxes, the whole waveform will be downloaded. For analog waveforms, this could mean as many as 4 million data points. If the user's modem speed is low, this data transfer could take as much as an hour. The from value gives the data start point. The to value gives the data end point. Plots of more than 1,000 data points do not show much detail. However, the user may download more points and then use the zoom function of gnuplot to display smaller segments. (See the GNUPlot manual.)

Because calculations and data reductions on entire waveforms are compute-intensive, these computations can be done on the FRED Data Server before the data is downloaded. Calculations are selected by clicking on the circle next to the desired item. Data reductions are selected by clicking on the down arrow box next to the "points by" box and then clicking on the desired selection.

Calculation and data reduction functions may both be applied to the selected waveform. If both are selected, the calculation is applied first, followed by the data reduction function.

#### Calculations:

- Selecting Integrate causes the integral of the waveform over the selected set of points to be downloaded.
- Selecting Integrate Squared causes the integral of the square of the waveform over the selected set of points to be downloaded. (This is useful for calculating Action Integrals of current waveforms.)
- Selecting Differentiate causes the derivative of the waveform over the selected set of points to be downloaded.

#### Data Reduction:

The various data reduction options are offered so that the user can get an overall perspective of a given waveform. For each of the following data reductions, a number, *n*, must be entered in the Reduction Points field. If no number is entered before selecting the data reduction option, a divide-by-zero error occurs, which causes FRED to shut down.

- Averaging causes the average value of each interval of *n* points to be downloaded. If there is a gap in the data in an interval, the average value of that interval is set to the gap value.
- Decimating causes every *n*th point to be downloaded.
- MinMax causes the minimum point and the maximum point of each interval of *n* points to be downloaded. If there is a gap in the data in an interval, the minimum and maximum values of that interval are set to the gap value.

“Set data to zero below” and “and above” fields are used to filter out noise. These fields define Y axis values, between which all data points are set to 0. The purpose is to hide the noise values in that range, particularly for integration and differentiation.

When the user is satisfied with the selections in this window, clicking on the Download box starts the process of downloading a file.

**NOTE:** The Internet connection **MUST** be established before the user clicks on the Download button for the download to be successful. (See paragraph 3.7.) In addition, the user should be aware that downloading files will require space on the specified drive.

If the user has selected an existing file name for the file to be downloaded, a Question window will open asking if the user wants to overwrite an existing file. If the user clicks on Yes, the process

continues and the file is overwritten. If the user clicks on No, the Desired Attributes for Plotting Waveform #n becomes the active window so that the user may change the file name.

#### 13.1.1 Downloading a File.

When the user requests to download a file, the User Identification window is opened. The user will need to type both his user ID and password in the appropriate boxes. **Do not press <Enter> to move from one box to the other. Pressing <Enter> initiates the action.** If no password has been entered, the download will be initiated but then terminated. An Error window will be opened with the following message: **STOP Windows Sockets Error: Valid name, but no data record.** Clicking on OK returns the user to the Desired Attributes for Plotting Waveform #n window.

When the user presses <Enter> or clicks on OK in the User Identification window, a Status Information window is opened with the following message: File is being downloaded. If the user is not connected to the INEEL, the download will be initiated but then terminated. An Error window will be opened with the following message: **STOP Windows Sockets Error: Valid name, but no data record.** Clicking on OK returns the user to the Desired Attributes for Plotting Waveform #n window.

If the user is connected to the FRED Data Server, a window will be opened notifying the user that the file has been received. Once receipt has been acknowledged, a window is opened to ask if the user wants to plot the file. If the user clicks on No, the Waveform #: n window is active. Changes may be made to any field in this window except the File Name field. If the user makes changes and clicks on download, the revised waveform will be downloaded, replacing the existing plot.

If the user clicks on Yes, GNUPlot is invoked and displays the waveform.

#### 13.2 PLOTS FOR WAVEFORM #:n.

If waveforms have already been downloaded for this flash, clicking on the **Request/View Plots** icon causes the Plots for Waveform #:n window to be opened. This window displays information on the waveforms that have already been downloaded. Using icons at the side of the window, the user may Add, Delete, Modify, or Plot subset waveforms.

##### 13.2.1 Add.

Clicking on the Add box in the Plots for Waveform #:n window causes the Desired Attributes for Plotting Waveform # n window to be opened. The functioning of this window is described in section 13.1.

##### 13.2.2 Delete.

Clicking on the Delete box in the Plots for Waveform #: n window causes a Question window to be opened. This window allows the user to verify that the waveform record and file are to be deleted. Clicking on the No box in this window returns the user to the Plots for Waveform #: n window with

no action taken. Clicking on the Yes box in this window returns the user to the Plots for Waveform #: n window with the originally highlighted waveform no longer in the waveform list.

Note that if the user has copied waveform files to a backup medium, returning these files to the directory in which *FRED* resides is not sufficient. When a file is deleted through *FRED for Windows*, internal *FRED* records are also changed.

### 13.2.3 Modify.

Clicking on the Modify box in the Plots for Waveform #: n window causes the Desired Attributes for Plotting Waveform # n window to be opened. The functioning of this window is described in paragraph 13.1. Note that this window is used to change the attributes for a given waveform. The waveform name may not be changed, but the attributes for that waveform may be changed. The revised waveform will replace the existing waveform. In other words, modify should not be used to get additional waveforms, but to correct or change existing waveforms.

### 13.2.4 Plot.

Clicking on the Plot box in the Plots for Waveform #: n window causes the graphics package GNUPlot to be opened in a gnuplot window. GNUPlot then plots the highlighted waveform in a gnuplot graph window. Only one plot may be displayed at a time. If a second plot is requested, an Error window is opened with the message: STOP Windows Execute Error: Cannot load second instance of multiple data segment application. Clicking on OK clears the message. To plot another waveform, the user must close the gnuplot window.

## 14. CLOSE ICON.

When the user clicks on the **Close** icon, *FRED for Windows* is closed down. No information is saved for the user. The **SQL** icon may or may not close. The gnuplot and gnuplot graph windows are not closed. (Closing the gnuplot window automatically closes the gnuplot graph window.)

## 15. HIERARCHY OF WINDOWS—MENUS.

Pull-down menus are located at the top of the screen. Table 7 describes the options available under the various menus. Clicking on the menu title reveals the selected menu. When a menu opens, the user may notice that some of the selections on the menu appear faded. Faded elements are not available to the user. Clicking on a faded element does nothing. Menus may be closed by clicking on the menu title or by pressing <Escape>.

TABLE 7. MENU DESCRIPTIONS

<p>File—Provides Basic Background Operations</p> <ul style="list-style-type: none"> <li>• Open—opens the following data windows <ul style="list-style-type: none"> <li>Sources</li> <li>Report</li> <li>SQL Report</li> <li>Environmental</li> </ul> </li> <li>• Printer Setup—allows the user to change the default printer</li> <li>• Print—prints data from the active window</li> <li>• Save to File—saves data from the active window to a file selected by the user</li> <li>• Plot Location—allows the user to change the default path for Default Min/Max and Default Peak plots</li> <li>• Plot Host Options—allows the user to change the address of the Host (Not generally used.)</li> <li>• Close—closes <i>FRED for Windows</i></li> </ul>
<p>Rows—Limits Data In Reports and Files</p> <ul style="list-style-type: none"> <li>• Sort—rearranges data based on sort columns; user may choose ascending or descending sorts</li> <li>• Filter—limits data based on filters selected by the user</li> <li>• Detail—rearranges data to print on one page</li> </ul>
<p>Plot—View Plots</p> <ul style="list-style-type: none"> <li>• Default Min/Max—1,000 data points across the whole waveform</li> <li>• Default Peak—1,000 data points around the peak value of the waveform</li> <li>• Request/View—allows the user to download waveforms from the FAA Server or view plots which have been previously downloaded</li> </ul>
<p>Window—Rearrange Windows and Icons</p> <ul style="list-style-type: none"> <li>• Cascade—overlap windows so that the top borders are visible</li> <li>• Layer—arrange windows on top of one another</li> <li>• Tile and Tile Horizontal—arrange windows so that all windows are visible</li> <li>• Icons—rearrange icons at the bottom of the desktop</li> </ul>
<p>Help—Access Online Help Screens</p>

## 16. FILE MENU.

### 16.1 OPEN.

Clicking on Open in the File menu opens a submenu which allows the user to open sources, reports, SQL reports, and environmental data and plots.

#### 16.1.1 Sources.

Clicking on Sources in the Open menu opens the Sources window, as described in paragraph 5.1.



### 16.1.2 Report.

Clicking on Report in the Open menu opens the Ad Hoc Reporting window, as described in paragraph 6.1.

### 16.1.3 SQL Report.

Clicking on SQL Report in the Open menu opens the SQL Query window, as described in section 7.

### 16.1.4 Environmental.

Clicking on Environmental in the Open menu opens the Query Limits window, as described in section 8.

## 16.2 PRINTER SETUP.

Clicking on Printer Setup in the File menu opens the Printer Setup window. This allows the user to change his local printer and printer options in Windows without having to leave *FRED for Windows*. Printers that the user has already defined are displayed. Windows manuals may be consulted for more information on these functions.

## 16.3 PRINT.

Clicking on Print in the File menu causes *FRED for Windows* to print information from the active window. Since printing is done through the Windows Print Manager, clicking on Cancel while the PC is preparing the print job cancels the job.

## 16.4 SAVE TO FILE.

Clicking on Save to File in the File menu causes the Save Rows As window to be opened, as described in section 10.

## 16.5 PLOT LOCATIONS.

Plot Locations allows the user to specify directories where *FRED for Windows* will store plot files. Clicking on Plot Locations opens the Default Plot File Location(s) window. In this window, the user may change the directory in which the Min/Max Plot files will be saved and the directory in which the Peak Plot files will be saved. These directories do not have to be the same.

Clicking on the Save button in the Default Plot File Location(s) window causes the new directories to be saved and closes the window. Clicking on the Cancel button in the Default Plot File Location(s) window causes the window to close without changing the directories.

## 16.6 PLOT HOST OPTIONS.

Plot Host Options allows the user to specify the Host on which the complete FRED waveforms reside and the port number. Clicking on Plot Host Functions opens the Plot Server Information window. In this window, the user may change the name of the Plot Host or the Port Number.

There are two IP addresses that will access FRED at this time:

- holodeck.inel.gov at 134.20.4.50
- gate-holodeck.inel.gov at 134.20.163.43

Both can be accessed at port 5080.

The software is preset to the correct address. If the connection to the remote system fails, the Host Option can be used either to enter the IP dot address (i.e., at 134.20.4.50, bypassing the name server) or to use the other IP address (i.e., holodeck.inel.gov). This option may be used in the future if the remote server is moved to a different server. You will be notified formally of this change if it should occur.

Clicking on the Save button in the Plot Server Information window causes the new directories to be saved and closes the window. Clicking on the Cancel button in the Plot Server Information window causes the window to close without changing the directories.

## 16.7 CLOSE.

Clicking on Close causes *FRED for Windows* to be shut down. No information is saved for the user. The **SQL** icon may or may not close. The gnuplot and gnuplot graph windows are not closed. (Closing the gnuplot window automatically closes the gnuplot graph window.)

## 17. ROWS MENU.

### 17.1 SORT.

Clicking on the Sort field under the Rows menu causes the Specify Sort Columns window to be opened. The user selects columns on which to sort by clicking on the desired column and pressing the left mouse button while dragging the item into the Columns block. Ascending sort is selected when there is an x in the box next to the column name. Ascending is the default. The user may change from ascending to descending (and back) by clicking on the box under Ascending.

When more than one column is selected for sorting, the data will be displayed in the order determined by the first column. Records with the same value in this column will further be sorted in the order determined by the second sort column. Records with the same entry in the first and second sorts columns will be further sorted in the order determined by the third sort column, and so forth.

Double-clicking on a column in the Specify Sort Columns window, causes the Modify Expression window to be opened. This window is the same as the Specify Filter window and allows the user to filter the data at the same time as the sort is being performed.

## 17.2 FILTER.

Clicking on Filter under the Rows menu causes the Specify Filter window to be opened. The user may select columns from the Columns block and functions from the function boxes or the Functions block by clicking on the desired item. The desired item will appear in the working block. If an argument is required for a function, the argument indicator will be highlighted in the working block. When the user clicks on a function or column, the argument indicator will be replaced by the item on which the user clicked.

It is not required that the user select items using a mouse. While the cursor is in the working block, the user may enter information from the keyboard. This can be faster if the user knows the required commands, but is risky since there is no spell checker provided.

When the cursor is in the working block, the user may type column names or other information. Using the <Tab> and <Back Tab> keys, the user may highlight function blocks. Pressing <Enter> while a function block is highlighted causes the function to be entered into the filter definition.

Clicking on the Verify box causes FRED to review the request typed in the working block. The Verify function opens a DataWindow that will contain one of two messages: "Filter is OK." or "Expression is not valid.", or it may contain an indication of the error identified.

This window may be closed without applying a filter by clicking on Cancel. When the user clicks on OK, the filter is applied if it is valid. If the filter is not valid, a DataWindow window opens containing the message: Expression is not valid. Clicking on the OK box closes the DataWindow and returns the user to the Specify Filter window.

## 17.3 DETAIL.

Clicking on Detail causes a Detail window to be opened. This window contains additional information for the highlighted item. The format is such that the information would fit on one printed page, should the user desire to print it.

## 18. PLOT MENU.

### 18.1 DEFAULT MIN/MAX.

The results of clicking on Default Min/Max in the Plot menu are the same as clicking on the **Plot the default minmax waveform** icon as described in section 11.

### 18.2 DEFAULT PEAK.

The results of clicking on Default Peak in the Plot menu are the same as clicking on the **Plot the waveform around the peak** icon as described in section 12.

### 18.3 REQUEST/VIEW.

The results of clicking on Request/View in the Plot menu are the same as clicking on the **Request/View Plots** icon as described in section 13.

## 19. WINDOW MENU.

### 19.1 CASCADE.

The Cascade function is used to rearrange windows and icons which are open on the desktop. Clicking on Cascade in the Window menu causes opened windows to be offset such that the top frame of each window and any icons at the bottom of the desktop are visible. Up to seven windows can be displayed in this way (depending on whether there are icons at the bottom of the desktop). If more than seven windows are open, later windows will completely overlay earlier ones. The active window will be on top.

### 19.2 LAYER.

Clicking on Layer in the Window menu causes opened windows to be expanded to fill the desktop. The active window will be on top. No other windows (or icons at the bottom of the desktop) will be visible.

### 19.3 TILE AND TILE HORIZONTAL.

Clicking on Tile or Tile Horizontal in the Window menu causes opened windows to be arranged so that the icons at the bottom of the desktop and the contents of all windows can be seen at the same time. The more windows and icons there are, the smaller each individual window will be.

The opened windows are positioned in matrix fashion. Tile causes there to be more columns than rows. Tile Horizontal causes there to be more rows than columns.

### 19.4 ICONS.

Clicking on Icons in the Window menu rearranges icons at the bottom of the desktop. This feature has no effect on the running of *FRED for Windows*. It merely makes things look neater if icons have gotten dragged out of line.

## 20. HELP.

Help can be reached through both the **Help** icon and the Help menu. The user may invoke help when most windows are active. The exceptions to this are pop-up windows which require a response from the user. No other action can take place until the user acknowledges the message in the window.

Help has two different actions when invoked by the user. If there is only one topic which is appropriate to the active window, that help topic will be displayed. If more than one topic is

available, the search screen is displayed so that the user may select the topic which best suits his or her needs.

If the user invokes help with no active windows, the help table of contents is displayed. The user may select topics from the table of contents or use the keyword search function.

## 21. GENERAL INFORMATION ON DATA PROCESSING.

### 21.1 COMPUTATION OF PEAK-RELATED VALUES.

The Peak Value is defined as the point in the waveform with the greatest absolute value.

The Peak Rise is defined as the greatest slope between two adjacent points in the waveform having the same sign as the peak value. Its location is considered to be the first of the two points which define it.

$$\text{Peak\_Rise} = \max(\text{abs}((y_i - y_{i-1})/dt)), \quad i = 2, \text{npts}$$

Time to Peak Value is the total time from pulse initiation to peak value.

Time to Half Maximum is the total time from pulse initiation to the first point which equals or exceeds half of the peak value.

Full Width at Half Maximum is the total time from the first point prior to the peak value which equals or exceeds half the peak value, to the first point after the peak value, which is less than or equal to half the peak value.

### 21.2 DETERMINATION OF PULSE INITIATION/TERMINATION.

The determination of the time\_to\_peak, time\_to\_half\_max, and full\_width\_at\_half\_max peak-related values depend on the points where the pulse begins and ends. These points have been defined as shown below:

- a. Pulse Initiation—The last point in the waveform prior to the peak value, where four consecutive slope changes can be found through points which lie between the low and high epsilon values (described in paragraph 21.2.1).
- b. Pulse Termination—The first point in the waveform **after** the peak value, where four consecutive slope changes can be found through points which lie between the low and high epsilon values (described in paragraph 21.2.1).

#### 21.2.1 Computation of Epsilon Values.

The intent of the high and low epsilon values (h\_eps and l\_eps) is to define a range of values, where points within it may be considered noise and not part of the pulse. The computation of these values is given below:

For each set of 512 points in a data buffer, until  $h\_eps$  and  $l\_eps$  are found:

Compute the mean value of the first 256 points in the set and the following 256 points in the set. Call them **mean1** and **mean2**.

Compute the standard deviations of **mean1** and **mean2**. Call them **sd1** and **sd2**. If, then

$$(mean2 - 2*sd2) < mean1 < (mean2 + 2*sd2) \text{ and} \\ (mean1 - 2*sd1) < mean2 < (mean1 + 2*sd1)$$

Compute the mean of the entire 512 points (MEAN);

Compute the standard deviation (SD) of this mean;

$$\text{Set } l\_eps = \text{MEAN} - 2*SD$$

$$\text{Set } h\_eps = \text{MEAN} + 2*SD$$

Do not accept  $h\_eps$  or  $l\_eps$  unless  $h\_eps > 0$

Otherwise, go on to next set of 512 points in the buffer.

If, during the use of these epsilon values, it is determined that the choices for their values produce unacceptable values for the calculation, an amount equaling one-tenth of the peak value is added to  $h\_eps$  and subtracted from  $l\_eps$ . This is repeated until calculations using these values produce reasonable results.

### 21.3 ERROR COMPUTATION.

While usually straightforward, the data conversion process for FRED calculated three derived values of interest. Two of the values provide expected errors for the charge transfer and action integral for current waveforms. The description of their calculation follows in this section.

The charge transfer is the integral (over some defined pulse duration) of the current. Similarly, the action integral is the integral (over the same pulse duration) of the square of the current. To obtain the true current values for use in the integration, it is necessary to remove from the digitizer output any offsets due to background or digitizer shift. The baseline value,  $I_{base}$ , whose determination was described earlier, is assumed to represent the digitizer output in the absence of any current flow. Thus, it should be subtracted to obtain the true value of the current.

The pulse duration is a matter of interpretation, but is limited by the pulse initiation and pulse termination times previously defined. Note that the definitions used for pulse initiation and termination are somewhat self-scaling in the sense that they attempt to identify stable returns to the baseline of the current waveform. This should be effective in capturing a continuous series of relatively fast oscillations as well as in capturing a single long duration, slowly changing pulse but will not pick out an individual outstanding peak within a series.

To give the FRED user a feel for the expected accuracy of the charge transfer and action integral calculations, two error quantities are computed for each quantity. A statistical error is calculated in order to set the scale of random fluctuations in the measurement process. A systematic error is also calculated and mainly represents the uncertainty associated with the baseline determination. The procedure for estimating the errors follows.

The waveform is divided into sets of ten points each. For each of the sets, the means of the current and square of the current are calculated, eliminating spurious contributions.

$$\bar{I}_j = \sum_{i=1}^{10} (x_{i,j} - x_{base}) \quad (1)$$

$$\bar{I}_j^2 = \sum_{i=1}^{10} (x_{i,j} - x_{base})^2 \quad (2)$$

where:

- $i$  is the sample index within the set
- $j$  is the set index in the waveform
- $J$  is the total number of sets in the waveform
- $x_{base}$  is the baseline value for the current
- $x_{i,j}$  is the value of the  $i$ th sample in the  $j$ th set
- $\alpha$  is the error associated with the determination of the baseline value

For each set, the standard deviations are computed for the current,  $s_{1,j}$ , and square of the current,  $s_{2,j}$ , using

$$s_{1,j} = \sqrt{\sum_{i=1}^{10} [(x_{i,j} - x_{base}) - \bar{I}_j]^2} \quad (3)$$

$$s_{2,j} = \sqrt{\sum_{i=1}^{10} [(x_{i,j} - x_{base})^2 - \bar{I}_j^2]^2} \quad (4)$$

From the  $J$  sets of values and deviations, a subset is selected for averaging to obtain quantities to be used to represent the deviations of the current and square of the current for the entire waveform. To select the subset, a variable width band symmetric about the current baseline value is defined. The width of the band,  $\Delta r$ , is adjusted until one half the sets,  $n_r$ , satisfy

$$-\Delta r \leq \bar{I}_j \leq \Delta r \quad (5)$$

where

$$n_r = J/2.$$

Then the mean deviations of the current,  $e_{1,r}$ , and the square of the current,  $e_{2,r}$ , are

$$e_{1,r} = \frac{1}{n_r} \sum_{j=1}^J f_{j,r} \overline{s_{1,j}} \quad (6)$$

and

$$e_{2,r} = \frac{1}{n_r} \sum_{j=1}^J f_{j,r} \overline{s_{2,r}} \quad (7)$$

with

$$\begin{aligned} f_{j,r} &= 1 \text{ if equation 5 is satisfied,} \\ &= 0 \text{ if equation 5 is not satisfied.} \end{aligned}$$

This procedure assumes that at least half of the waveform has no signal or that the signal value changes little over a ten sample interval. In this case, reasonable root mean square (rms) estimates are obtained for the random fluctuations associated with current and the square of the current. If there is significant change in signal values within many of the  $n_r$  selected sets, these rms estimates will be exaggerated and the statistical error estimates for charge transfer and action integral will be similarly exaggerated. With this in mind, the estimated statistical error on the charge transfer is

$$E_{C,stat} = (\sqrt{N_{pulse} \Delta t}) e_{1,r} \quad (8)$$

where

$$\begin{aligned} N_{pulse} &\text{ is the number of samples between initiation and termination of the pulse} \\ \Delta t &\text{ is the sampling interval for the waveform} \end{aligned}$$

The estimated systematic error on  $C$ , the charge transfer, is

$$E_{C,sys} = (N_{pulse} \Delta t) \alpha \quad (9)$$

The estimated statistical error on  $A$ , the action integral, is

$$E_{A,stat} = \sqrt{N_{pulse} (\Delta t e_{2,r})^2 + 4A \Delta t e_{1,r}^2} \quad (10)$$

The estimated systematic error on the action integral is

$$E_{A,sys} = |\alpha [\alpha (N_{pulse} \Delta t) - 2C]| \quad (11)$$



The estimated error,  $E_C$ , on the charge transfer and the estimated error,  $E_A$ , on the action integral may then be represented as

$$E_C = \pm E_{C,stat} \pm E_{C,sys} \quad (12)$$

and

$$E_A = \pm E_{A,stat} \pm E_{A,sys} \quad (13)$$

The chief value of these error estimates is in evaluating the significance of values of charge transfer and action integral calculated for a waveform. The size of the estimated error relative to the calculated value must be small for charge transfer or action integral quantities to be useful.

### 21.3.1 Noise Waveform Determination.

Not all of the sensors available on the aircraft detected appreciable signal from the strike. This meant that several of the waveforms consisted of nothing but the underlying noise inherent in the system. The conversion process performs calculations that attempt to identify these "uninteresting" waveforms. This algorithm was also developed by Dr. J. Elliott.

There are three tests that can be performed on a waveform. The first test consists of selecting 10 sets of 10 points each at uniform locations over the waveform. Each set is used to calculate a mean and standard deviation. The 10 means are tested pairwise for consistency of being measurements of a single value. A (generous) 10 standard deviation difference is allowed before a pair is judged as coming from different underlying distributions. If this test is exceeded, the waveform is judged as having some signal and not being a noise waveform, and the second and third tests are not applied. Most waveforms containing a signal will be detected by this test, meaning that, normally, the second and third tests are not applied.

The second and third tests are described in the following steps:

- a. Calculate the standard deviation and mean over the entire waveform.
- b. Calculate the delta, which is the factor used to scale the digitizer count into actual data values.
- c. Calculate the bandwidth for use in the final iteration. If the number of points outside the calculated band is zero, a noise waveform has been identified. (Second test.)
- d. Calculate the final bandwidth. If no points are found outside this band, a noise waveform has been identified. (Second test.)
- e. Scan the waveform one more time. If two consecutive points are found outside the band, a non-noise waveform has been identified. (Third test.)

## 22. CV-580 DATA.

### 22.1 FULL-SCALE VALUE.

#### 22.1.1 Definitions.

Full-scale value is the largest magnitude which can be measured for a given quantity. This value is determined by the sensor, its signal processing circuitry, and the recording and playback instrumentation. There is also a level, which may be equal to or smaller than the full-scale value, above which the sensor/recording system response is no longer linear with respect to the primary quantity being sensed. This level is known as the saturation threshold. Saturation can occur in a number of ways (e.g., saturation of the gain of an amplifier in the signal processing circuitry or saturation of the analog recording magnetic tapes). These forms of saturation usually result, at least initially, in an increased output for an increased input but with a reduced proportionality factor (i.e., gain compression). On the other hand, a digitizer has an input limit corresponding to its maximum digitized output; any and all signals exceeding this input yield the same fixed output.

For the data digitized from the CV-580 analog recorder, the measurement quantity presented to the user (from the report EMA-90-R-35) is calculated using the following formula:

$$D = F_s * F_r * F_d * (5.12/2048) * (\text{sample value} - 2048) \quad (14)$$

where D is the scaled data;  $F_s$  is the Sensor Scale Factor (SSF) (physics units divided by the sensor voltage);  $F_r$  is the Record Scale Factor (RSF) (the sensor voltage divided by the tape voltage); and  $F_d$  is the Data Scale Factor (DSF) (the digitizer counts divided by the sample value units). The factor (5.12/2048) is the tape unit voltage divided by the digitizer counts.

#### 22.1.2 Full-Scale Value.

Full scale is obtained when the sample value achieves its maximum value of 4096. Thus, the full-scale value is as follows:

$$\text{Full-Scale Value} = F_s * F_r * F_d * 5.12 \quad (15)$$

#### 22.1.3 Saturation Threshold.

In general, the CV-580 instrumentation was set up to give linear response, as long as the voltage presented to the analog recorder ( $V_{\text{tape unit}}$ ) was less than 1.4 v (i.e., less than 1  $v_{\text{root-mean-square}}$ ). This implies that the saturation threshold is as follows:

$$\text{Saturation Threshold} = F_s * F_r * F_d * 1.4 \quad (16)$$

### 22.2 SCALE FACTORS.

There are three scale factors for each channel of data recorded: SSF, RSF, and DSF. SSF is defined from the sensor, and the circuitry that followed it, transforming the physical quantity

a voltage input to the tape recorder. RSF is the ratio of input of the recorder in record mode to the output in playback mode. This factor could be set manually by the tape operator. DSF is used to account for the different quantization levels of the Frequency Modulation (FM) and Direct channels. These scale factors are necessary to get properly scaled values from the data and are all recorded in the data records. To convert the data from the units stored in the file into physical units, use equation 1.

The FM channel sample values are stored in two bytes, while the Direct channel sample values are stored in a single byte.

#### 22.2.1 1984 Scale Factors.

In 1984, the SSFs were derived from two handwritten documents: a list of the scale factors and calibration data for the JS sensors and the set of circuit diagrams. These documents are consistent; however, the circuit diagram for the JS sensors does not show the low channel. The only change during the year was on September 5, 1984, the final recording date for that year, for the JNFF-L and JNFF-H channels.

The documentation for the 1984 data was difficult to obtain due to the length of time between data acquisition and digitization. The main difficulty was determining the gain settings on the analog tape recorder to get the RSF. A reference signal was recorded, however, at the beginning of most of the tapes to be used to compute these gain settings. The signal was recorded at the beginning of the first tape used on a given flight and on the subsequent tapes of that flight if time permitted. Reference signals were found for four of the five flights in 1984. This reference signal was not found on the 1985 or 1987 data tapes, although an exhaustive check was not done. The July 11, 1984, files, for which no signal was found, have the same scale factors as the July 13, 1984, data, since no other information was available.

When recorded, this reference signal was fed into an input on the tape drive, recorded on all channels simultaneously, and appropriately scaled according to the gain setting on each channel. The signal was a square wave of 100 Hertz (Hz) with no direct current component. When recorded on an FM channel, the square wave is well preserved and reproduced, because most of its energy was in band. Since the low frequency -3 decibel point is 400 Hz for the direct channels, much of the energy in the 100 Hz square wave is filtered out on these channels. Fourier analysis reveals that, although the signal loses much of its energy and shape, the peak is preserved around the transition points.

The amplitude of the recorded signal was assumed to be 10 volts peak to peak, based on the original design specification for the signal source. The tape scale factor for a given channel was, therefore, determined by playing the tape and observing the peak value ( $V_p$ ) of the recorded signal on an oscilloscope and dividing into five:

$$\text{Scale Factor} = 5/V_p \quad (17)$$

### 22.2.2 1985 Scale Factors.

In 1985, the SSFs were given in two documents. One is a portion of a BASIC program listing used to process the data and the other is a set of circuit diagrams for the sensors. The factors did not change during the year in either document with the exception of one channel. The program listing shows the ILW-L SSF as changing from 6.9 to 5.0 on the last strike. However, this change is most likely an error. The other factor for this channel is not listed. Ignoring this channel, the documents do not agree for seven other channels.

Also, there is no drawing of a JSFF-L channel in the circuit diagrams. Since the program listing is more recent and should include any modifications to the hardware since the initial design, it was used as the source for these factors. The low channel of all the current shunts has a scale factor of about 250 in both documents, so the ILW-L channel factor was also set to this value.

The RSFs are described in two documents, also not entirely consistent: the BASIC program listing described above and the Honeywell setup documents for 1985. There were two changes in RSFs in 1985. However, the dates listed on the changes do not agree for the final set of changes. The date listed on the setup document does not include the final strike, but there is no page showing another set of changes for that date. Tables 8 through 12 show the information contained in the two documents.

The Honeywell setup document was used in the event of a discrepancy, because it is believed this record was created at the time the tape drive was adjusted. The final set of scale factors was extended to include the final strike.

TABLE 8. 1985 SENSOR SCALE FACTOR DISCREPANCIES

Channel	Sensor	Circuit Diagram	Program Listing
2	JSFF-L		600
4	JSFF-H	306	600
5	JNFF-H	220000	$9.43 \times 10^{-7}$
6	JSLW	306	600
7	JNFF-L	110000	$4.55 \times 10^{-7}$
16	JSRW	306	600
18	JSAF	306	600
20	IDOT	3200	72

### 22.2.3 1987 Scale Factors.

In 1987, the SSFs were derived from a single document. Therefore, no discrepancies occurred.

The RSFs were obtained from the same document, as well as the Honeywell setup for that year, and both sources agreed.

TABLE 9. 1985 RECORD SCALE FACTOR DISCREPANCIES

Channel	Sensor	D1	PL1	D2	PL2	D3	PL3
2	JSFF-L	1.39	1.4	1.39	1.4	1.39	2
3	TRIGGER	0.694	1.0	0.694	0.69	0.694	1
4	JSFF-H	6.94	6.9	6.94	6.9	6.94	5
5	JNFF-H	6.94	6.9	2.00	2.0	6.94	5
6	JSLW	6.94	6.9	6.94	6.9	6.94	5
7	JNFF-L	6.94	6.9	2.00	2.0	6.94	5
8	ILW-H	6.94	6.9	6.94	6.9	6.94	5
9	JNLW	6.94	6.9	5.00	5.0	6.94	5
10	ILW-L	6.94	6.9	6.94	6.9	6.94	5
11	JNRW	6.94	6.9	3.33	3.3	6.94	5
12	IRW-L	6.94	6.9	6.94	6.9	6.94	5
13	EFR	1.04	1.04	1.04	1.04	1.04	1
14	IRW-H	6.94	6.9	6.94	6.9	6.94	5
15	JNVS	6.94	6.9	3.47	3.5	6.94	5
16	JSRW	6.94	6.9	6.94	6.9	6.94	5
17	BDOT	6.94	6.9	6.94	6.9	6.94	5
18	JSAF	6.94	6.9	6.94	6.9	6.94	5
19	HFR	1.04	1.04	1.04	1.04	1.04	1
20	IDOT	6.94	6.9	6.94	6.9	6.94	5
21	LWW1	1.04	1.04	1.04	1.04	1.04	1
22	ITB-H	6.94	6.9	6.94	6.94	6.94	5
23	LWW2	6.94	1.04	6.94	1.0	6.94	1
24	ITB-L	6.94	6.9	6.94	6.9	6.94	5
25	VHF120	1.39	1.04	1.39	1.4	1.39	2
26	IVS-H	6.94	6.9	6.94	6.9	6.94	5
28	IVS-L	6.94	6.9	6.94	6.9	6.94	5

D1 = Honeywell setup document (May - 24 June)

PL1 = Program listing (May - 24 June)

D2 = Honeywell setup document (26 June - 24 July)

PL2 = Program listing (26 June - 24 July)

D3 = Honeywell setup document (25 July - 27 August)

PL3 = Program listing (25 July - End of project)

TABLE 10. 1984 CHANNEL MAP AND SCALE FACTORS

Channel	Sensor	DIR/ FM	RSF 11 JUL	RSF 13 JUL	RSF 07 AUG	RSF 17 AUG	RSF 05 SEP	SSF 11 JUL- 04 SEP	SSF 05 SEP	DSF	Units
1	TIME CODE	FM	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	JNLW (HIGH)	DIR	8.33	8.33	12.50	11.10	10.00	8.85E-7	8.85E-7	16	C/m**2
3	TRIGGER	DIR	1.19	1.19	1.19	1.19	1.19	1	1	16	V
4	JNLW (LOW)	DIR	4.17	4.17	5.56	5.56	4.44	8.59E-8	8.59E-8	16	C/m**2
5	JNFF (HIGH)	FM	10.00	10.00	12.50	10.00	12.50	9.96E-7	1.99E-7	1	C/m**2
6	ILW (HIGH)	DIR	3.13	3.13	5.00	4.55	4.55	5.1E3	5.1E3	16	A
7	JNFF (LOW)	FM	9.10	9.10	12.50	11.10	12.50	5.05E-8	1/00E-7	1	C/m**2
8	JSLW (HIGH)	DIR	5.26	5.26	7.14	7.14	7.14	467	467	16	A/m
9	JSFF (HIGH)	DIR	5.00	5.00	7.14	7.14	7.14	519	519	16	A/m
10	JSLW (LOW)	DIR	5.56	5.56	7.14	8.33	7.14	50.4	50.4	16	A/m
11	JSFF (LOW)	DIR	7.69	7.69	10.00	10.00	10.00	55.7	55.7	16	A/m
12	JSRW (LOW)	DIR	4.17	4.17	6.25	6.25	5.88	54.0	54.0	16	A/m
13	JSF (LOW)	DIR	4.17	4.17	6.25	7.14	5.88	55.1	55.1	16	A/m
14	JSRW (HIGH)	DIR	8.52	8.52	6.25	6.25	6.25	510	510	16	A/m
15	JSF (HIGH)	DIR	2.86	2.86	4.55	4.55	4.34	513	513	16	A/m
16	IRW (HIGH)	DIR	5.56	5.56	7.14	7.14	7.13	5.1E3	5.1E3	16	A
17	JNVS (LOW)	DIR	3.33	3.33	5.56	6.25	5.26	8.59E-8	8.59E-8	16	C/m**2
18	JNRW (LOW)	DIR	6.25	6.25	8.33	10.00	7.69	8.59E-8	8.59E-8	16	C/m**2
19	JNVS (HIGH)	DIR	4.17	4.17	5.56	6.25	5.56	8.85E-7	8.85E-7	16	C/m**2
20	JNRW (HIGH)	DIR	5.56	5.56	7.14	8.33	7.14	8.85E-7	8.85E-7	16	C/m**2
21	VHF63	FM	5.00	5.00	8.33	8.33	4.54	1	1	1	V
22	IRW (LOW)	FM	8.33	8.33	12.50	11.10	11.10	200	200	1	A
23	EFR	DIR	1.19	1.19	1.92	1.56	1.19	1	1	16	V
24	ILW (LOW)	FM	7.69	7.69	12.50	12.50	11.10	200	200	1	A
25	HFR	DIR	1.25	1.25	1.67	1.67	1.25	1	1	16	A/m
26	VHF63	DIR	2.50	2.50	3.33	3.33	1.25	1	1	16	V
27	TACH	DIR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	VHF120	DIR	1.25	1.25	1.25	1.67	1.33	1	1	16	V

TABLE 11. 1985 CHANNEL MAP AND SCALE FACTORS

Channel	Sensor	DIR/FM	RSF MAY-24 JUN	RSF 26 JUN-24 JUL	RSF 25 JUL-27 AUG	SSFDS	F	Units
1	TIME CODE	FM	N/A	N/A	N/A	N/A	N/A	N/A
2	JSFF (LOW)	DIR	1.39	1.39	1.39	600	16	A/m
3	TRIGGER	DIR	0.694	0.694	0.694	1	16	V
4	JSFF (HIGH)	DIR	6.94	6.94	6.94	600	16	A/m
5	JNFF (LOW)	FM	6.94	2.00	6.94	9.43E-7	1	C/m**2
6	JSLW	DIR	6.94	6.94	6.94	600	16	A/m
7	JNFF(HIGH)	DIR	6.94	2.00	6.94	4.55E-7	16	C/m**2
8	ILW (HIGH)	DIR	6.94	6.94	6.94	2.94E3	16	A
9	JNLW	DIR	6.94	5.00	6.94	8.9E-7	16	C/m**2
10	ILW (LOW)	FM	6.94	6.94	6.94	247	1	A
11	JNRW	DIR	6.94	3.33	6.94	89E-7	16	C/m**2
12	IRW (LOW)	FM	6.94	6.94	6.94	247	1	A
13	EFR	DIR	1.04	1.04	1.04	1	16	V
14	IRW (HIGH)	DIR	6.94	6.94	6.94	2.94E3	16	A
15	JNVS	DIR	6.94	3.47	6.94	8.9E-7	16	C/m**2
16	JSRW	DIR	6.94	6.94	6.94	600	16	A/m
17	BdotTB	DIR	6.94	6.94	6.94	35.6	16	A/m
18	JSAP	DIR	6.94	6.94	6.94	600	16	A/m
19	HFR	DIR	1.04	1.04	1.04	1	16	V
20	IdotTB	DIR	6.94	6.94	6.94	72	16	A
21	LWW1	DIR	1.04	1.04	1.04	1	16	V
22	ITB (HIGH)	DIR	6.94	6.94	6.94	2.94E3	16	A
23	LWW2	DIR	6.94	6.94	6.94	1	16	V
24	VHF120	FM	6.94	6.94	6.94	247	1	A
25	IVS (HIGH)	DIR	1.39	1.39	1.39	1	16	V
26	TACH	DIR	6.94	6.94	6.94	2.94E3	16	A
27	IVS (LOW)	DIR	N/A	N/A	N/A	N/A	N/A	N/A
28		FM	6.94	6.94	6.94	247	1	A

TABLE 12. 1987 CHANNEL MAP AND SCALE FACTORS

Channel	Sensor	DIR/FM	RSF 16 JUL-11 AUG	RSF 30 JUL	SSF	DSF	Units
1	TIME CODE	FM	N/A	N/A	N/A	N/A	N/A
2	OPT1	DIR	6.94	6.94	1	16	V
3	TRIGGER	DIR	0.694	0.69	1	16	V
4	JSFF	DIR	4.90	0.69	4.E9	16	A/m/s
5	JNFF(LOW)	FM	6.94	6.94	1.95E-6	1	C/m**2
6	JSAF	DIR	4.90	0.69	4.E9	16	A/m/s
7	JNFF(HIGH)	FM	6.94	6.94	9.74E-7	1	C/m**2
8	JSLW	DIR	4.90	0.69	4.E9	16	A/m/s
9	JNLW	DIR	6.94	6.94	8.8E-7	16	C/m**2
10	JSRW	DIR	4.90	0.69	4.E9	16	A/m/s
11	JNRW	DIR	6.94	6.94	8.8E-7	16	C/m**2
12	ILW(LOW)	FM	6.94	6.94	250	1	A
13	JNVS	DIR	6.94	6.94	8.8E-7	16	C/m**2
14	ILW(HIGH)	DIR	6.94	6.94	3.E3	16	A
15	BdotTB	DIR	6.94	6.94	35.6	16	A/m
16	IRW(LOW)	FM	6.94	6.94	250	1	A
17	OPT2	DIR	6.94	6.94	1	16	V
18	IRW(HIGH)	DIR	6.94	6.94	3.E3	16	A
19	OPT3	DIR	6.94	6.94	1	16	V
20	ITB(LOW)	FM	6.94	6.94	250	1	A
21	OPT4	DIR	6.94	6.94	1	16	V
22	ITB(HIGH)	DIR	6.94	6.94	3.E3	16	A
23	OPT5	DIR	6.94	6.94	1	16	V
24	IVS(LOW)	FM	6.94	6.94	250	1	A
25	OPT6	DIR	6.94	6.94	1	16	V
26	IVS(HIGH)	DIR	6.94	6.94	3.E3	16	A
27	TACH	DIR	N/A	N/A	N/A	N/A	N/A
28	IdotTB	DIR	0.694	0.69	2.E9	16	A/s



## 23. NASA F-106 DATA.

### 23.1 NASA DIRECT LIGHTNING STRIKE PROGRAMS, 1982 THROUGH 1984.

During 1982, 1983, and 1984, a lightning-instrumented F-106B aircraft was flown by the NASA Langley Research Center. The flights took place in a region within 150 miles of Hampton, Virginia, where the aircraft was based. A variety of sensors were used to record the electromagnetic response of the F-106B. The primary quantities sensed were the following:

- External magnetic flux density time derivative
- External electric flux density time derivative
- External current
- External current time derivative
- Internal wire current

The data sampling intervals ranged from 5 to 40 nsec at different times for different sensors. The digitized record included either 65,000 or 131,000 samples with pretrigger sampling varying from 1/8 to 1/4 of the total time record. More than 2,000 electromagnetic response waveforms associated with nearby or direct strikes to the aircraft were recorded during the 3 years.

Because of the usual experimental difficulties with the onboard instrumentation in a severe environment and because of offboard transcription difficulties, some of the waveforms contained spurious values. These spurious values were recognized and corrected or eliminated by the original researchers at NASA in their analysis and publication of the data (Thomas and Pitts 1983, Thomas 1985, and Thomas and Carney 1986). One of EMA's major tasks was to ensure that such spurious data was eliminated from the waveforms submitted to FRED. Furthermore, a positive confirmation of agreement with the NASA published data was desired. The procedures adopted to achieve these goals will be described in section 23.3.

### 23.2 INTRODUCTION.

Before the F-106B waveforms were received by EMA, extensive processing had already taken place. Unfortunately, calibrated full-time records of the original waveforms no longer existed. This necessitated repeating the transcription from the original analog flight tapes as well as the calibration conversion to American Standard Code for Information Interchange (ASCII) computer tapes with waveform data in engineering units.

The flight tapes contained dumps of the digitizers' memories for each trigger by a lightning event. A Pulsed Coded Modulation (PCM) format was used to store a majority of the digital data on the analog tape. The data transcription facility at the NASA Langley Research Center handled the transfer of the data from analog tapes to 9-track computer tapes. Following transcription, calibration information was applied to the raw digitizer data and 9-track computer tapes were written with flight information (see table 13) and the waveform data in an ASCII format. These were the input tapes to the processing by EMA.

TABLE 13. F-106B HEADER ENTRIES

Column <sup>1</sup>	Delta	Disk <sup>2</sup>	Abbrev.	Description	Examples
1	1			Continuation (1) or Comment (1) character	1, 1
2-6	5		FLT	Year; Flight Number (YYFFF)	83030
8-11	4		DATE	Date (MMDD)	0705
13-16	4		EVNT	Event (N=Nearby1 S=Strike) Number	N001, S010
18-19	2		RN	Transcription Run Number	01, 12
21-23	3	**	PEN	Penetration Number	002
25	1		L	Last Record=1; Otherwise=0	1
27-30	4		SEN	Sensor (leading 1=Integration)	ODP, 1BL, T123
32-37	6		EU	Engineering Units	A/m <sup>2</sup> , T/s
39-40	2		ns	Sampling Interval (ns)	05, 10
42-44	3		FU	Presample Filter (MHz)	50; 200
46	1		FL	Low Frequency Cutoff	0
48-53	6		UT	Universal Time (HHMMSS)	201503
55-56	2		Fs	Fractional UT(TH)	33
58-60	3		DIG	Biomation (100 or 200); LeCroy (X,Y)	100; 2.1
62-67	6		MEM	Memory Size	131072; 65536
69-73	5		PTRIG	Pretrigger	25% <sup>3</sup> , 8192 <sup>4</sup>
75-78	4		TRSO	Trigger Source	IND <sup>5</sup> , BL <sup>6</sup>
80-84	5	**	ALT	Altitude (ft)	30954
86-89	4	**	EDIS	Distance (km) from SPANDAR (+E, -W)	-223, 146
91-94	4	**	NDIS	Distance (km) from SPANDAR (+N, -S)	227, -123
96-98	3	**	TMP	Outside Air Temperature (C)	-35
100-102	3	**	TAS	True Airspeed (m/s)	245
104-107	4		TRSO	Addition Trigger Source (ORed)	DWR, DWL
109-112	4		TRSO	Addition Trigger Source (ORed)	DWR, DWL

- <sup>1</sup> Enter spaces in unidentified columns  
<sup>2\*\*</sup> Obtained from storm hazard database  
<sup>3</sup> Percent of memory size  
<sup>4</sup> Pretrigger samples  
<sup>5</sup> Independently triggered digitizers  
<sup>6</sup> Sensor trigger source

### 23.3 DATA PROCESSING.

#### 23.3.1 Data Dropout.

The age and deteriorated condition of the flight tapes precluded use of 1980 and 1981 data. In addition, some tapes from 1982 and 1983 were unable to be processed. In addition to the total loss of a waveform, it was possible that errors on a small portion of tape would cause the loss of data for a limited number of samples. Because of the recording technique, these partial data losses occurred as integral multiples of the basic PCM transcription unit (32 samples for the Biomation digitizers in

1982 and 1983 and 128 samples for the LeCroy digitizer data in 1983 and 1984). Although the data was lost for these samples, it was desired to maintain the relative timing of the good samples following those on the bad areas of tape. Since it was thought that the number of lost samples could be identified, during the calibration conversion an equal number of special valued samples were inserted in the record as space (actually time) holders. This procedure for dealing with data dropout was developed by Computer Resource Management, the original contractor working with the transcribed waveforms.

The data loss was mainly associated with the Biomation digitizer data, because it was older and had a less robust PCM recording technique. It was not unusual to see waveforms for which as much as 25 percent of the data had been lost. Unfortunately, the space holding technique seemed to suffer confusion easily and it was not unusual to see waveforms with considerably more data than the digitizer could have recorded. Consequently, the timing of different waveform features in the Biomation digitizer data is not necessarily well preserved. Since the Biomation digitizers triggered independently, this problem has little additional impact in comparing the timing of features in different waveforms. The LeCroy digitizers had various combinations of common triggers, but no significant timing problems were observed in this data.

### 23.3.2 File Format.

The data format for the waveform files sent to the INEEL for input to FRED was the same as that used in previous efforts described in Ng<sup>1</sup> and Elliott (1992), Ng<sup>2</sup> and Elliott (1992), Elliott and Ng (1991), Elliott and Weigel (1990), and Thomas and Pitts (1983). The salient features are as follows:

- a. 4096 byte ASCII header record containing all waveform information, except for the sensor time record.
- b. Blocks of 4096 8-bit binary values, one for each of the sampled data points.

#### 23.3.2.1 Header Record.

The basic format of the header records is a 20-character descriptor followed by a 60-character value for each of the fields. The information is obtained from the following sources:

- NASA header information
- Storm Hazards Database (Fisher et al., 1988)
- EMA processing

#### 23.3.2.2 Binary Waveform Data.

The waveform data is encoded according to the following formula:

$$\text{data sample [units of data]} = \text{scale factor} * (\text{binary value} - \text{dig. offset}), \quad (18)$$

where the **units of data**, the **scale factor**, and the **dig. offset** are obtained from the header record, and the binary value is one of the 8-bit values corresponding to a sampled data point.

An 8-bit value corresponding to 255 is a special value signifying the absence of reliable data at that point in the sampling series. This value can originate in two different ways. The first was discussed in section 23.3.1. In this case, values of 255 are merely place holders for data lost during the transcription process at NASA. The second source of 255 values comes from the removal of spurious data points by EMA in the data filtering process described below. In this case, a value of 255 is also a place holder. Note that the maximum binary value for the LeCroy digitizers is necessarily reduced to 254 to preserve the special function for the value 255.

### 23.3.3 Data Processing Procedures.

A series of procedures was used to process the data, combining computer automation and human attention. The goal was to process as many waveforms as possible under the available funding, while ensuring that the data passed on to FRED was useful and free of spurious values. The multistep procedure was chosen to maximize the throughput by eliminating, as quickly as possible, the waveforms that could not be salvaged with a reasonable amount of effort. The steps were as follows:

- a. Conversion from ASCII to compact floating point format.
- b. Conversion from floating point to 8-bit binary format and addition of header information in a header block.
- c. Removal of spurious data identified by computer program.
- d. Inspection of waveform plots—full-time record and regions of peaks.
- e. Waveform data inspection and hand editing, if necessary.
- f. Submission of accepted waveforms to the INEEL for FRED input, one tape per flight.

Summaries of the steps are given in the following subsections.

#### 23.3.3.1 ASCII to Floating Point Format Conversion.

At this step all of the files on tape were read from the tape (supplied by Galaxy Scientific Corporation (GSC)) and written to disk. In the process, the data values, read as a three-digit scientific notation ASCII quantities, were written to disk using the computers internal floating point representation. This represented a data compression of more than a factor of four.

#### 23.3.3.2 Floating Point to 8-Bit Conversion.

For this step, the floating point numbers were compressed to 8-bit values, according to equation 21, with the appropriate decoding factors generated for storage in the header record. The header record was also generated at this time using the header information on the input tape and information from the Storm Hazard Database.

At this point, a first quality check was made by comparing the DSF, obtained from the relevant NASA publication (Thomas and Pitts (1983), Thomas (1985), and Thomas and Carney (1986)), with the one derived from the least common denominator of input data. Agreement at the level of a few percent was required for progression to the next step. Only a few isolated waveforms failed this test, with the exception of the 1983 Biomation digitizer BDOTWL sensor data for flights 11 through 42. All of these waveforms were lost at this step.

#### 23.3.3.3 Computer Removal of Spurious Data.

The next step performed the automated removal of spurious data from the waveforms. The basic approach has been described in some detail, with multiple examples in Ng<sup>2</sup> and Elliott (1992). The only difference in this project from the previous work is that the point is marked as nondata, as opposed to trying to provide a corrected value as was done previously. Basically, the change in value between successive time samples is examined for consistency with the local waveform behavior. Particular algorithms deal with known digitizer and transcription failure modes. An example of a readily recognizable type of spurious data is a value which is similar to its neighbors, except for the high order bit of its binary representation being set on. This is common failure mode of digital electronics and data, showing that a signature should be removed, which, in this case means having its 8-bit value set to 255.

#### 23.3.3.4 Inspection of Waveforms.

To prepare for visual inspection of the waveforms, two sets of plots were made. The first set displayed the full-time record of the waveform as originally received, as well as after the automatic spurious point removal. The second set of plots also displayed before and after data but only for smaller time sections of the waveforms. The shorter time sections that were displayed duplicated those displayed in the NASA publications (Thomas and Pitts (1983), Thomas (1985), and Thomas and Carney (1986)). In addition, an automatic process selected sections of waveforms, wherein a value change of 8 or greater occurs in between successive points. This allows examination of sections of the waveform that exhibit either interesting structure or contain spurious data. Of course, this is more effective with the 8-bit LeCroy digitizers than with the 6-bit Biomation digitizers.

After generating the plots, each waveform was compared to published plots in the appropriate NASA publication. For acceptance, it was required that a NASA plot exist and that the EMA plots agree with the NASA plots for the waveform. In addition, extra plots generated by EMA were required to be reasonable. In the case of a discrepancy between the NASA and EMA plots, it was determined that a limited amount of manual editing of the data could resolve the difference.

Usually this meant marking spurious data as nondata, and sometimes it meant restoring points which were erroneously removed by the computer program used in the previous step.

A classification scheme was adopted for the inspection step. The most interesting labels used for waveforms with the possibility of acceptance were as follows:

- 0—Waveform accepted without manual processing.
- 1—Waveform requires limited manual processing, after which it may (or may not) be accepted.
- 2—Waveform could be salvaged, but requires effort outside the present scope.

#### 23.3.3.5 Data Editing.

Data editing was a time-intensive process; therefore, every attempt was made to limit its application to waveforms with only a few points (generally less than 5) which required human intervention. The procedure required specification of a small time interval, including the suspect data. Both the original and EMA processed versions of the data were displayed for comparison. If modification was required, the changes were made manually through the computer system editor.

#### 23.3.3.6 Data Submission.

The physical format of the data submitted to the INEEL for input into FRED was the same as that used previously. A 9-track computer tape was used to hold the waveforms associated with each flight. The naming scheme for the tapes was as follows:

FNAABB

where AA are the last two digits of the year (e.g., 82), and  
BB is the two-digit flight number (e.g., 17).

Each file on the tape was named according to the following convention:

AA0BBSSSQ...Q.DAT

where AA and BB are as in the tape label,  
SSSS is the strike label (initial S for direct strike, N for nearby strike), and  
Q...Q is the sensor tag.

Table 14 lists the sensor definitions, as well as the tags used in the file name construction.

TABLE 14. LIST OF SENSOR ABBREVIATIONS, EXPLANATIONS, AND FILE TAGS

Header	Explanation	File Tag
BWL	Time derivative of magnetic flux density on left wing	BDOTWL
BWR	Time derivative of magnetic flux density on right wing	BDOTWR
DT	Time derivative of electric flux density on tail	DDOTT
IDT	Time derivative of nose boom current	IDOT
BL	Time derivative of magnetic flux density produced by longitudinal fuselage current	BDOTL
DWR	Time derivative of electric flux density on right wing	DDOTWR
DWL	Time derivative of electric flux density on left wing	DDOTWL
DF	Time derivative of electric flux density on lower forward fuselage	DDOTF
IT	Tail current	I-TAIL
VFA	Defined in NASA TM87690, 1984 Direct Strike Lightning Data	VFA
VFB	Defined in NASA TM87690, 1984 Direct Strike Lightning Data	VFB
VFC	Defined in NASA TM87690, 1984 Direct Strike Lightning Data	VFC
VW	Defined in NASA TM87690, 1984 Direct Strike Lightning Data	
T123	Defined as TP123 in NASA TM87690, 1984 Direct Strike Lightning Data	TP123
T114	Defined as TP114 in NASA TM87690, 1984 Direct Strike Lightning Data	TP124
T116	Defined as TP116 in NASA TM87690, 1984 Direct Strike Lightning Data	TP116
T125	Defined as TP125 in NASA TM87690, 1984 Direct Strike Lightning Data	TP125
T100	Defined in NASA TM87690, 1984 Direct Strike Lightning Data	TP100
T101	Defined in NASA TM87690, 1984 Direct Strike Lightning Data	TP101
T102	Defined in NASA TM87690, 1984 Direct Strike Lightning Data	TP102

#### 23.3.4 1982 Data.

In 1982, two channels (denoted 100 or 200) of Biomation digitizers were used for data acquisition. The digitizers had a 6-bit range and a 131,072 sample length with a 10 nsec sampling period. The channels were triggered independently by the same waveform being digitized. Thomas and Pitts (1983) specify the sensors and their locations, polarities, and ranges.

There was considerable degradation of the 1982 flight tapes, which resulted in numerous data errors, in addition to those generated during the original data acquisition. As a result, many waveforms were lost because of excessive data loss and contamination. Less than 50 percent of the files received from GSC were submitted for inclusion in FRED.

#### 23.3.5 1983 Data.

Flights 11 through 42, from the 1983 F-106B effort, were conducted with the same Biomation digitizers used in 1982. The data had many of the problems observed in the 1982 waveforms. Furthermore, the scale factors for BDOTWL used by GSC disagreed with those published by NASA. Later investigation by GSC determined that the NASA publication was correct for flights 11 through 16, but some confusion remains concerning flights 17 through 42. In any case, none of those BDOTWL 1983 waveforms were submitted to the INEEL.



Beginning with flight 44, a set of four LeCroy digitizers (three channels each) were used for onboard data acquisition. These units had an 8-bit range and stored 65,536 samples. A 10 nsec sampling period was used. Thomas (1985) details the F-106B instrumentation and configuration for the 1983 flights. In general, the LeCroy digitizer data received by EMA was of much higher quality and had fewer problems.

#### 23.3.6 1984 Data.

The LeCroy digitizers were used exclusively during the 1984 flights. Sampling intervals varied from 5 to 40 nsec for various sensors at different times. Several different triggering schemes were used on multiple sensor/channel combinations. A great deal of high-quality data was acquired simultaneously for many sensors in 1984.

A sensor labeling discrepancy between header information on the GSC supplied tape and the NASA publications prevented generating expanded plots for the examination of fine structure in some of the waveforms. This occurred for the wire measurements involving both induced currents and voltages. Thomas and Carney (1986) contains a more detailed description of the 1984 data and its acquisition. Nearly 80 percent of the 1984 waveforms received from GSC were accepted for FRED.

#### 23.3.7 Waveform Saturation.

When examining a waveform for its maximum value, it is also useful to know whether the value is a true maximum or merely the upper limit of the digitizer's range. To deal with this issue, a table of possible minimum and maximum values was compiled for each accepted waveform. The data received by EMA had undergone an arbitrary baseline subtraction (i.e., the waveform zero in engineering units was not the same as the original digitizer zero). GSC supplied a microcomputer diskette with baseline values that had been used for zero subtraction processing. A distinct baseline value was associated with each waveform. Usually this was the value observed just before the digitizer triggered. EMA used the baseline values with scale factors (also supplied by GSC) to compute the least count as well as the minimum and maximum value for each waveform. A DOS diskette containing these results is part of this report. The data is in ASCII format with the following four fields for a waveform on a line:

least count	minimum value	maximum value	waveform label
-------------	---------------	---------------	----------------

#### 23.4 SUMMARY.

Selected for input into FRED were 1,022 F-106B direct strike lightning waveforms with their auxiliary flight information. The data was acquired with two Biomation digitizer channels in 1982 and part of 1983 and with 12 LeCroy digitizer channels in part of 1983 and all of 1984. The Biomation data contained 131,072 samples per waveform, while the LeCroy data contained 65,536 samples per waveform. The time resolution was typically 10 nsec, but ranged from 5 nsec to 40 nsec. Deterioration of the aging magnetic flight tapes reduced the original data set of over 2,000 waveforms to the 1,596 received by EMA for processing. First-order consistency and data quality checks further reduced the number of candidate waveforms to 1,369 for the 3 years.



The entire data record of each candidate waveform was visually inspected for reasonableness and compared to results published by NASA. If a higher resolution NASA plot existed for an interesting subsection of the waveform, a similar plot was created by EMA and a comparison was made. In addition, an automated procedure produced plots of any regions with a significant structure. Existence of a NASA plot, and agreement with it, was a prerequisite to waveform acceptance. Reasonableness of the data was required. In some cases, spurious data was identified and replaced by a special nondata value. Similar data removal had been performed by NASA. The processing and acceptance procedures employed a combination of automatic computer processing, human inspection, and data manipulation.

## 24. FRENCH TRANSALL DATA.

### 24.1 OVERVIEW.

The French government sponsored a research program studying lightning strikes to aircraft in flight using a C-160 Transall aircraft. This propeller driven aircraft was outfitted with a variety of electromagnetic sensors and flown in thunderstorm conditions.

The data provided to the FAA for inclusion in FRED were recorded in 1986 and 1988. In 1986, current and surface current density information was collected. This data was provided by the Centre d'Essais Aeronautique de Toulouse (CEAT) in the form of 14-track analog tape recordings of sensor outputs. Data from 1988 was made available from ONÉRA. This included data digitized onboard during the flights/strikes as well as an offline digitization of analog data originally recorded on 28-track tapes during the flights. Details of these data collections, their extent, format, and content are treated in separate sections.

### 24.2 1986 DATA.

CEAT was responsible for the 1986 C-160 flight data. The original 14-track analog data tapes were provided to EMA along with a three-part report (in French) on the 1986 program. Unfortunately, since none of the original personnel were still involved with the data, there was effectively no interaction beyond this. Therefore, it was impossible to extract the same level of header information as was available for the 1988 data. Some meteorological data was obtained through a translation of one part of the 1986 document. The main concentration of this lightning campaign was on external currents.

According to the CEAT documents, nine in-flight lightning strikes were recorded in 1986, although one of these strikes (the last) contained two events separated by 2 seconds. This strike was treated as two for the purposes of digitization. It should also be noted that strike number 3 was not present on the tapes received by EMA.

The digitization of the 1986 C-160 analog tapes was similar to the digitization of the CV-580 analog tapes (Elliott and Ng, 1991). Logically, the task was the same with only some procedural differences. The steps are:

- a. A 14-track Honeywell 101 playback apparatus was employed.

- b. The digitization was triggered by an IRIG-B time decoder.
- c. All the channels were FM Wide Band Group 2 with 0-500 kHz bandwidth. These were digitized at 1 Megasample per second with a range of  $\pm 2.048$  V with 12-bit digitized sample.
- d. Each data channel for an event was digitized simultaneously with the trigger channel. It was anticipated that waveform shifting could be employed for time synchronization as was done for the digitized 1988 C-160 analog data. However, comparison of the digitized trigger signals, for both repeats of the same data channel and for different data channels, revealed that the time decoder repeatability was on the order of 5 samples or 5  $\mu$ s. Therefore, no further effort was invested in waveform shifting.
- e. The data was transferred to a Sun Microsystems workstation via file transfer protocol (ftp) for further processing. This was a great improvement over the general purpose instrument bus (GPIB) transfer to a VAX-11/780 in the CV-580 digitization project.
- f. It was noted that different sensors/channels had major differences in the maximum levels on the analog tape. The data was compressed from 12 bits to 8 bits by using dynamic scaling for each waveform. That is to say, the extreme value was set to  $\pm 126$  and all other values were scaled proportionately.

The scale factors for the low-frequency and high-frequency current sensors were taken from the CEAT document listed in the bibliography. As suggested by the same document, the scale factors for the H fields (surface current densities) were obtained by a comparison between the voltage waveform obtained with the digitizer and the waveform plotted with actual physical units in the report. In the cases of a clear signal, it is estimated that the scale factors obtained in this fashion have an average accuracy of 10 percent and an upper error limit of 25 percent. In the absence of significant signal in the document plots, only the noise range could be used and in this case the errors on the scale factors could be considerably larger. If there is no signal, this should not be a major difficulty, but care should be taken in trying to extract limits or averages using the waveforms. It is also true that if significant peaks occur outside the time interval shown in the CEAT documents, their absolute values are not as reliable.

### 24.3 1988 ANALOG DATA.

The 1988 C-160 data was provided by ONÉRA for inclusion in FRED. The flights over the south of France yielded a total of 13 strikes. However, requiring that the instrumentation was functioning well enough for analog recording of at least 80 percent of the physical parameters reduced the useable number of strikes to ten. Of these ten, eight also had digital signals recorded onboard the aircraft.

As part of ONÉRA's participation in the project, 18 sensor channels were digitized from the 28-track analog tape record. The original recording format was FM (Wide Band Group 2) with a

passband of 0-500 kHz. An 8-bit digitizer with a sampling rate of 1 Megasamples per second was used to acquire approximately 2 seconds of data.

ONÉRA's digitization process was able to handle only three channels simultaneously. The desire to maintain proper time registration among all 28 data and 1 trigger channels prompted the repeated recording of the trigger channel with each pair of data channels. Although this allowed recovery of the channel-to-channel timing, it presented an awkward situation for the waveforms in FRED. Offsets of more than 100 ms were observed. If the offsets were not corrected, intrastrike waveform comparisons in FRED would require a rather tedious determination of the time offset and subsequent shifting of the plots.

As a result, the decision was made to perform the shifting prior to entering the data into FRED. The procedure compared significant edge transitions in the various digitizations of the trigger channel to obtain the relative timings of all channels. All subsequent digitizations were shifted to match those of the first triplet of channels. Note that after shifting, the synchronization appears to be on the order 10 samples or 10  $\mu$ s. The same number of data samples was maintained by inserting the binary data value of 255 (invalid data) at either the beginning or end of the data as required by the direction of the time shift.

#### 24.4 1988 DIGITAL DATA.

The 1988 digital data was collected onboard by Tektronix TEK 7612 AD and TEK RTD 710 digitizers. Their key parameters are:

<u>TEK 7612 AD</u>	<u>TEK RTD 710</u>
20 ns interval	200 ns interval
8-bit accuracy	10-bit accuracy
2048 samples	32768 samples
496 pretrigger	16,000 pretrigger

The data was provided in the format of ASYST data files. When decoded, these data files contained channel number, sensor label, digitizer type, pretrigger, and scale factors. This information was integrated with that provided in the supporting documentation. It should be noted that when there were discrepancies between the data files and the report, the information in the data files was used.

For each of the 11 lightning strikes, there were a total of 26 channels of sensor data digitized onboard.

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## 26. GLOSSARY.

ACTION INTEGRAL. For current sensors, the integral of the current waveform squared over a time interval ( $\int i^2 dt$ ). The time interval is defined by the integration start and the integration stop times.

AFFILIATION. The organization sponsoring research for a given researcher.

AIRSPEED. The speed (in knots) at which the aircraft was traveling for an airborne research project.

AIR TEMPERATURE. Temperature of the air at the location of the sensor at the time of the strike.

ALTITUDE. For airborne sensors, the height (times 100 feet) of the sensor above ground when the flash occurred. For ground-based sensors, the elevation above sea level of the sensor. If this field is "-9999," the actual value was unknown.

ANALOG RECORDER ID. A code indicating the analog recorder on which the data was recorded. This corresponds to an entry in the analog recorder description table and can be viewed by invoking the help function.

ATTACH POINT. The initial point of contact of the strike with the aircraft.

CHARGE TRANSFER. The amount of electric charge transferred during the strike. This value is calculated only for current sensors. The time interval is defined by the integration start point and integration end point.

DATA SCALE FACTOR. Digitizer counts divided by the sample value units.

DATA UNITS. Units of the waveform specified.

DATES. The upper and lower limit dates between which the user wishes to select data.

DECIMATE. A FRED command that keeps every nth point, where the number n is specified by the user in the Reduction Points field.

DETACH POINT. The final point of contact of the strike with the aircraft.

DIGITIZER ID. A code indicating the digital recorder on which the data was recorded or the digitizer which processed the analog data. This corresponds to an entry in the digitizer description table.

ELECTRICAL PHENOMENA. Information about the electrical phenomena observed by the crew around the time of the lightning strike. There may be more than one entry in this block.

FILE NAME. Names of plot files in the user's directory.

FILTER. A FRED command that sets all points within a specified range to zero.

FLASH DATE. The date the strike occurred.

FLASH ID. A number that identifies the flash. These numbers are assigned consecutively by the program that enters data into FRED. They are used internally by FRED to track the data.

FULL SCALE. The largest magnitude that can be measured for a given quantity. This value is determined by the sensor, its signal processing circuitry, and the recording and playback instrumentation.

FULL WIDTH AT HALF MAX. The width of the peak measured from the point where the waveform first reaches half of the peak value to the point where the waveform first returns to half of the peak value.

INITIAL STRIKE TIME. A value of time calculated by assigning the strike time to the point on the trigger channel where the trigger spike was recorded. The time interval between the beginning of the recording and the strike time is subtracted from the strike time. This gives the time of the initial sample point.

INTEGRATE. A FRED command that integrates over a specified interval.

INTEGRATION START. The lower integration limit used to calculate the action integral and the charge transfer.

INTEGRATION STOP. The upper integration limit used to calculate the action integral and the charge transfer.

KNOTS. Nautical miles.

LATITUDE. The latitude at which the strike was recorded. This value is given as two digits for the degrees, two digits for the minutes, and two digits for the seconds. The direction (north or south) is carried and reported in a separate field. If the latitude of a CV-580 strike is not known, a default value of 28:00:00 N latitude is used. If the latitude of an F-106 strike is not known, a default value of 38:00:00 N latitude is used. If the latitude of a C-160 strike is not known, a default value of 43:30:00 N latitude is used. In addition, if the seconds or minutes are shown as "00," the value is probably estimated.

LONGITUDE. The longitude at which the strike was recorded. This value is given as three digits for the degrees, two digits for the minutes, and two digits for the seconds. The direction (east or west) is carried and reported in a separate field. If the longitude of a CV-580 strike is not known, a default value of 81:00:00 W longitude is used. If the longitude of an F-106 strike is not known, a default value of 75:00:00 W longitude is used. If the longitude of a C-160 strike is not known, a

default value of 1:30:00 E longitude is used. In addition, if the seconds or minutes are shown as "00," the value is probably estimated.

NUMBER OF POINTS. The number of data points in the waveform.

PEAK VALUE TIME. The location (in time) where the peak absolute value of the waveform occurred.

PEAK RISE. The instantaneous peak rate of rise. This quantity is determined by taking the slope of the line between adjacent pairs of points. The highest value so determined is entered in the Peak Rise field.

PEAK RISE TIME. The time during the strike at which the instantaneous peak rate of rise was recorded.

PEAK VALUE. The point of the waveform with the maximum absolute value.

PRECIPITATION. The types of precipitation observed by the crew around the time of the strike.

PRECIPITATION SEVERITY. The degree of precipitation observed by the crew.

RANGE. A FRED command that keeps all of the points between specified end points.

RECORD SCALE FACTOR. Sensor voltage divided by the tape voltage.

RESEARCHER. Names of the researchers involved in the collection of data for the associated source.

SAMPLING INTERVAL. The interval of time over which data was accumulated to yield one data point.

SAMPLING WINDOW. The interval over which the waveform was retained for FRED.

SATURATION. A value to denote that saturation was observed and noted by the researcher. Possible values are "Y," "N," and "U." "Y" indicates that the researcher noted saturation. "N" indicates that the researcher noted no saturation was present. "U" indicates that no observations were made concerning saturation.

SATURATION THRESHOLD. The threshold above which the equipment no longer produced a linear response.

SENSING PARAMETER. The quantity being measured by the sensor.

SENSOR ID. A code that indicates the sensor that acquired the data. This corresponds to an entry in the sensor description table.

SENSOR LOC. The location of the sensor, if a given test setup included more than one sensor.

SENSOR SCALE FACTOR. Physics units divided by the sensor voltage.

SOURCE NAME. An identifier for a collection of data. In general, data are grouped under some name which gives information about the program that collected the data. Data may be further subdivided by year if a program collected data for more than one year.

SOURCE TYPE. An indication of the type of data collected by a source. Options are "Airborne," "Ground based," or "Rocket triggered."

STRIKE TYPE. An indication of whether the strike attached to the structure where the sensor was located or merely passed near the sensor.

TEMPERATURE. The environmental temperature at the time of the strike. This temperature may have been recorded in Fahrenheit, Celsius, or Rankine degrees. All temperatures in FRED are listed in degrees Celsius.

TIME. The time at which the strike occurred. This time is taken from the data logs and/or is the time of the peak on the trigger.

TIME TO HALF MAX. The location (in time) of the data point where the waveform first reaches half of the peak value.

TIME TO PEAK. The location (in time) of the data point with the greatest absolute value.

TITLE. The top of two label lines permitted in the FRED scatter plots.

TOTAL NUMBER OF FLASHES. The number of lightning events recorded in a given source.

TRIGGER THRESHOLD. The value at which the recording devices were triggered to record. This value may not be known if the equipment could be triggered by more than one sensor.

TURBULENCE SEVERITY. Degree of turbulence observed by the crew.

USER PLOT COMMANDS. GNUPlot commands that the user can enter to enhance plots.

WAVEFORM ID. A number which identifies the waveform. These numbers are assigned consecutively by the program which enters data into FRED. They are used internally by FRED to track the data and by the user to request that a given waveform be loaded.

WAVEFORMS. The digitized representation of information acquired by a sensor over time.

X-AXIS LABEL. The information to be printed along the horizontal axis in FRED scatter plots.

Y-AXIS LABEL. The information to be printed along the vertical axis in FRED scatter plots.



# APPENDIX A—HELP AND ERROR MESSAGES

ERROR MESSAGE	RESULT OF ACKNOWLEDGING ERROR MESSAGE	ACTION BY USER
Application Error PBSTB040 caused a General Protection Fault in module PBSHR040.DLL at 0006:00CE	<i>FRED for Windows</i> may close; Windows may close.	If the application does not close, close it. Exit Windows to release resources. Try again.
Application Error PBSTB040 caused an illegal instruction in module GDI.EXE at 0007:0843.	The system returns to the DOS prompt.	Reboot computer. Restart Windows. Restart FRED for Windows.
Application Error PBSTB040 caused a Stack Fault in module PBRTF040 at 0005:EC46	FRED for Windows closes. Windows remains open and active. <b>SQL/FAA</b> icon remains on screen.	Close Windows to release resources. Try again.
Data Window ! Expecting NUMBER expression.	System reverts to the last active window.	Enter a numeric expression.
DataWindow Error ! Line 7 Column 8: incorrect syntax	Additional error messages may appear.	Continue to acknowledge the message until it clears.
Error STOP	Reverts to last active window.	
Error STOP File I/O Error: No such file or directory.	Reverts to last active window.	Ensure that the path selected is correct and that the device is online.
Error STOP No rows selected.	Clicking on OK returns the Environmental Plot Options window.	Reset the selection criteria.
Error STOP No sources found. Am closing the window.	Error window closes.	Contact the INEEL FRED DBA via email at faa@inel.gov.
Error STOP Timed out when resolving the host address from the host name.	Clicking on OK returns the Desired Attributes for Plotting Waveform #n window.	Check to see that the connection to the INEEL has been made. If the connection is active, perhaps the networks are overloaded. Trying again at a different time of day might help.

ERROR MESSAGE	RESULT OF ACKNOWLEDGING ERROR MESSAGE	ACTION BY USER
<p>Error</p> <p>STOP Wave Retrieval Error: Timed out when attempting to connect to the host.</p>		
<p>Error</p> <p>STOP Windows Socket Error: Valid name, but no data record.</p>	Acknowledging the error message returns the user to the Desired Attributes window.	Contact the INEEL FRED DBA via email at faa@inel.gov.
<p>Error</p> <p>STOP The lower latitude value is invalid it must be of the form DDD:HH:MM</p>	User is returned to the Query Limits screen.	Re-enter the data in the correct format.
<p>Error Creating Report</p> <p>! Line 242 Column 242: incorrect syntax</p>	The query is not processed. The query screen remains, however, no changes can be made.	This error occurs when the user tries to request too many columns. Reduce the number of columns in the query and resubmit it.
<p>File Error</p> <p>Cannot find WINSOCK.DLL</p>	Error R00014 is displayed.	Check that the communications software is available. Verify the path. If both are correct, contact your local network expert.
<p>GZIP.PIF</p> <p>! Cannot find file.  Check to ensure the path and filename are correct.</p>	Another Error window is opened.	Check to ensure that the path and filename are correct. Verify that the device is online. If problem persists, contact the INEEL FRED DBA via email at faa@inel.gov.
<p>PowerBuilder Application Execution Error (R0002)</p> <p>STOP Application Terminated.  Error: Null object reference at line 29 in clicked event of object m_filter of m_frame.</p>	FRED for Windows closed.	Restart FRED for Windows.

ERROR MESSAGE	RESULT OF ACKNOWLEDGING ERROR MESSAGE	ACTION BY USER
<p>PowerBuilder Application Execution Error (R0006)</p> <p>STOP Application terminated.</p> <p>Error: Invalid DataWindow row/column specified at line 12 in rowfocuschanged event of object dw_report of w_report.</p>	Program aborted.	Contact the INEEL FRED DBA via email at faa@inel.gov.
<p>PowerBuilder Application Execution Error (R00014)</p> <p>STOP Application terminated.</p> <p>Error: Error opening DLL library RETRFILE.DLL for external function at line 147 in clicked event of object pb_plot of w_plot2.</p>	Other error windows open.	Contact the INEEL FRED DBA via email at faa@inel.gov.
<p>PowerBuilder Application Execution Error (R0023)</p> <p>STOP Application Terminated</p> <p>Error: Cannot assign object of type w_plot_peakvalue_by_altitude to variable of type w_sources at line 87 in clicked event of object m_print of m_frame.</p>	Acknowledging the error causes FRED for Windows to close, leaving the <b>SQL/FAA</b> icon open. SQL/FAA closes ok.	Contact the INEEL FRED DBA via email at faa@inel.gov.
<p>PROGMAN (sic)</p> <p>An error has occurred in your application. If you choose Ignore, you should save your work in a new file. If you choose Close, your application will terminate.</p>		Choose either ignore or close. Exit Windows to release resources and review the section on General Protection Faults (paragraph 2.5.1).
<p>SQL Syntax Error</p> <p>I Only Select Statements Allowed</p>	SQL Query Window is reactivated.	Type a select query or close the SQL Query window.
<p>SQL Syntax Error</p> <p>SQLSTATE = 37000 [WATCOM][ODBC Driver]Syntax error: near 'where' in ...emd_waveform_id [where] source_id eq 1 ...</p> <p>select emd_waveform_id where source_id eq 1</p>	Returned to SQL Query screen.	Fix the query and resubmit it.

FRED for Windows	REQUESTOR:	DATE:
WINDOW:		
PROBLEM:		
HOW I ARRIVED AT THE PROBLEM:		
PROPOSED SOLUTION:		
ADDITIONAL COMMENTS:		
RESOLUTION:		
Disposition:		
Accepted As Written	Accepted As Modified	Rejected
Requestor notified by:		

FRED Users Manual	REQUESTOR:	DATE:
Page Number:	Chapter and Paragraph Number	Page Date
PROBLEM:		
PROPOSED SOLUTION:		
ADDITIONAL COMMENTS:		
RESOLUTION:		
Disposition:		
Accepted As Written	Accepted As Modified	Rejected
Requestor notified by:		